PHYSIOLOGY FOR HIGH SCHOOLS

MACY – NORRIS


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A GENERAL PHYSIOLOGY

FOR HIGH SCHOOLS

BASED UPON THE NERVOUS SYSTEM

BY

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"*The physiology of the nervous system is emphatically the physiology of the future.*" — MICHAEL FOSTER, M.D., F.R.S.

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PREFACE

The effort has been made in this book to unify the study of the parts and the functions of the human organism by the application of approved pedagogical and scientific principles. The teaching of any science proceeds logically from that which is known to that which is not known. Physiology is one of the earliest of the natural sciences to be presented for formal study in school. In respect to man's organism the one sort of knowledge absolutely original and elemental is *consciousness* — conscious motion and sensation. This it is that forms the most apparent difference between the two kingdoms which manifest the phenomena of life. It is characteristic of animals to possess consciousness, volition, feeling. Plants are, to all appearance, devoid of them all.

Hence this study of human physiology is made to begin with that part of the body which is the organ of consciousness — the *nervous system*. The pupil knows that he thinks and feels and wills and moves, and he studies physiology in order to understand the apparatus by which these wonders are accomplished. He is here given first (after a few preliminary definitions) a brief sketch of the parts composing the nervous system. Next he studies those physical operations into which consciousness enters as an essential quality, and becomes familiar with the organs of motion and sensation. This leads naturally to consideration of the provision for the sustenance of those organs — nutrition in its comprehensive sense. Finally the student comes to a more detailed examination of the mechanism for the conscious activities of the human being.

Whatever may be true of philosophers, the infant begins the study of physiology at the point here suggested, and follows a method in harmony with this plan. More than one practical teacher has worked out a similar method through years of experience in the class room. By making the nervous system (the center and core of all animal life) the leading thought throughout, a unity of impression is secured,

the actual connection of every vital process with the one nervous system becomes obvious, and the emphasis is placed where it properly belongs. It is believed that this plan has advantages also for the student of general biology. It emphasizes the one grand, obvious distinction between plants and animals. To students of psychology it will likewise commend itself. Because of prevalent ignorance of the nervous system and its due predominance in the animal economy, psychologists have been forced to become physiologists in order to build across the gap, left by the ordinary manner of treatment, between physiology and psychology.

Care has been taken to make no statements not in accord with established science, but no effort is made to introduce the newest conjectures. The necessary limitations of a school text-book have been kept in mind as well as the degree of mental development of those for whom the work is designed.

It is believed that the instruction respecting alcoholic drinks and narcotics, while complying with the requirements of recent legislation in the various states, will be found to be based upon rational and scientific principles, and to be placed before the student in a manner to win the assent of his reason rather than to create a mere prejudice which further knowledge might overthrow. Nothing is gained by overstatement, and it is always safe to tell the simple truth, for nothing will so surely foster right living as a knowledge of the truth.

The writer has had much assistance from experienced and competent teachers and physicians. Dr. A. W. Alvord (M.D., University of Michigan) of Battle Creek, Michigan, has kindly revised the hygienic portions of the book. Mr. H. W. Norris, A.M., Professor of Biology in Iowa College, has read and criticised the whole of the manuscript. All of the experimental work has been prepared by him and will be found of especial value. Many of the illustrations used are such as are commonly found in schoolbooks treating the subject of physiology, but a large number have been adapted from cuts in recent advanced works, mainly those by Morris, Spalteholz, and Van Gehuchten; while numerous other drawings expressly for this work have been made by Mr. E. W. Atherton under the direction of Professor Norris.

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PART I

INTRODUCTION

It is customary to divide the study of the human body into three departments: (1) *Anatomy*, which is the science that describes the structure of the body; (2) *Physiology*, or the science of the functions, or uses, of the various parts of the body, and (3) *Hygiene*, or the science of health, which treats of the care of the body and all its parts for the purpose of maintaining the whole in its best condition for usefulness and enjoyment. The term *Physiology*, as applied to a schoolbook, however, is often used to include all three of these lines of study.

Fig. 1. — The nervous system.

CHAPTER I

MATTER AND CELLS

1. Living and Lifeless Matter. — What matter is we are not yet able to say, but as it exists in our world it may be separated into two great divisions, — living matter and lifeless matter. So far as present knowledge goes, these two sorts of matter are wholly distinct the one from the other, and lifeless matter never becomes living matter except under the influence of matter already living. The same substances are indeed found in the two sorts of matter, and when living matter is killed, or becomes lifeless, no change can be discovered in its weight. That mysterious something called *life* is therefore not material, and living matter may be said to be only ordinary lifeless matter existing in a different state or condition.

2. Chemical Elements. — A substance which cannot be divided into two or more different kinds of matter is called a *chemical element*, or a simple substance. All others are called compound substances. Matter is separated into its elements by processes which affect the molecules or the atoms of which it is composed, that is, by chemical analysis.

A *molecule* may be defined as the smallest particle of matter which exists alone and retains most of the properties of the mass of the substance. An *atom* is one of the ultimate particles of which a molecule is composed. The

molecules of chemical elements are composed of atoms of the same kind. Compound substances have atoms of different kinds. There are as many kinds of atoms as of elements. Both atoms and molecules are too small to be seen even with powerful microscopes.

A drop of water may be divided mechanically into many small portions, and each part will retain all the characteristics of the original drop. But when the chemist separates the oxygen and hydrogen which together make up the drop of water, he has no longer any matter which resembles water, but instead two kinds of gaseous matter of entirely different properties. The water has been resolved by chemical analysis into its chemical elements.

Chemical elements unite in different proportions with one another to form a great variety of substances. About seventy-five elements have been isolated by chemists, but only a few of them are known to enter into the structure of animal bodies. These are carbon, oxygen, hydrogen, nitrogen, sulphur, phosphorus, chlorine, fluorine, silicon, potassium, sodium, lithium, calcium, magnesium, iron, and manganese. As a rule these elements exist in the body in some sort of combination with one another.

3. **Protoplasm** is a name given to living matter. It is a clear, jellylike substance containing minute grains. As protoplasm, it cannot be chemically analyzed, because the process of analysis destroys its vitality so that it is no longer protoplasm, but merely dead, lifeless matter. The one essential thing about protoplasm is that it is alive; dead protoplasm is a contradiction in terms. It has been called "the physical basis of life," because without it life does not exist, and with it there is always life. But the material of which protoplasm is composed is found, when

analyzed after it has ceased to live, to be highly complex. A large part of its weight is *water*, while its solid portion is chiefly composed of *proteids*. These are substances found in many foods, white of egg being a familiar example. They contain carbon, hydrogen, oxygen, and nitrogen.

4. The Cell (Fig. 2). — All living bodies, both plants and animals, are found to consist of cells. Cells are the ultimate units of which living beings are made up, just as bricks are the units of which a brick wall is composed. A *cell* is a microscopic bit of protoplasm, with or without an inclosing wall, having suspended within it a rounded body of denser material called the *nucleus*. It may be living apart, or may form one of the units of an organism. Plant cells have usually the cell wall, but an animal cell may be only a naked speck of living matter. Free cells tend to assume a round shape, but under pressure they may take almost any form.

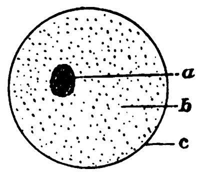


Fig. 2. — Diagram of the parts of a cell.

a nucleus.
b cell body or protoplasm.
c cell wall.

5. The cells of the human body vary in size from $\frac{1}{300}$ to $\frac{1}{3000}$ of an inch in diameter. All animals begin their existence as single cells, and the life of any animal is the sum of the activities of all its separate cells, while its physical structure consists of the cells themselves and the intercellular matter which they produce, together with the various lifeless substances which they deposit within themselves.

6. Essential Properties of Cells. — All living things possess two properties without which they cannot exist.

One of these properties is *nutrition*, — using the word in its broader sense to include the double process of taking

in material from outside and building it into the bodily structure, — that is, the making of complex chemical compounds out of simpler ones; and the breaking down, or reducing to simpler forms, of compounds already formed. The former results in growth or repair of cell substance, and is the storing up of energy; the latter is the setting free of energy, and the production of waste material to be removed as no longer valuable. Nutrition includes all the chemical changes which take place in living matter.

The other essential property of living bodies is the power of *reproduction*, or of giving rise in some way to living beings like themselves.

The first of these properties, nutrition, belongs to every individual cell, to every plant, and every animal, as necessary to its own continued existence. The second, reproduction, is needful only for the continued existence of the race, and is in some cases possessed only by certain individuals of the race. Single cells are, however, capable of giving rise by self-division to other cells like themselves.

Life is sustained by the ceaseless exercise of the two powers of nutrition and reproduction.

7. Other Properties of Living Cells. — Certain other properties are found to exist in most cells in the body, for example, in the white corpuscles of human blood, which are clearly defined nucleated cells.

These are *contractility*, or instability, that is, the power of changing form without the application of pressure; *irritability*, or the power of vigorous action under stimulus, as, for instance, when the blood cells contract under the influence of electricity; *conductivity*, or the power of passing on to distant parts of the cell the influence exerted by a stimulus upon a single point; and *coördination*, or the capacity in all the parts to work together in definite

direction and with regulated strength to accomplish an end, as when a particle of material suitable for building up a cell is drawn in and used for that purpose.

8. **Plants and Animals.** — No naturalist can at the present day place his finger upon a line of separation and say: All living things upon this side are plants; all upon that side, animals. It is, indeed, easy to distinguish the higher forms of animal life from the higher forms of plant life, and the most striking difference is that the animal possesses the power of spontaneous movement, while the plant is rooted to one spot. Other distinctions appear as the two forms of life are studied. For example, both are dependent for their continued life and growth upon the food which is supplied from without themselves; but plants (with few exceptions) subsist solely upon carbon dioxide, water, and mineral salts, while animals live upon water and those chemical compounds which have formed part of living bodies, that is, organic materials. Animals cannot use mineral substances as food except as they are mixed with organic matter. But the simplest forms of plant and animal life cannot be distinguished with positiveness from each other. Both consist of single protoplasmic cells, and it is not possible to show that the protoplasm of one is essentially different from that of the other.

As animals rise in the scale of being, however, they are found to develop, as plants do not, a nervous system of ever-increasing complexity and importance. Hence man, as an animal, may be said to be distinguished from all other animals by the superiority of his nervous system; and all the other parts of the human body may be considered as created simply to minister in some way to that superior portion of the human frame which is the direct agent or instrument of the highest manifestations of life.

9. The Difference between Plants and Animals in Respect to Stimulus. — Living animal cells possess the property of irritability or excitability, that is, some change in their composition results from the action of *stimulus*. Vegetable cells also possess this property in some degree. But it is found that, as in the processes of development more and more complex forms of plant life appear, the plant does not develop special organs for the transmission of stimulus. In the animal kingdom, on the other hand, a striking difference appears. In one of the lowest known representatives of animal life — the *amœba* (Fig. 3, p. 16), which is a mere microscopic lump of naked protoplasm — each minute particle of the protoplasm appears to respond to a stimulus and to transmit it to the adjacent particles, there being no distinction of parts or functions in the single cell. But in the next higher division of animals, the corals, sea anemones, etc., the rudiments of a nervous system are visible, and some division of sense organs appears. It is probable that nervous impressions are received first in but a single form, while a gradual and uninterrupted development of the senses follows as we rise in the scale. That is, one of the lower animals may be said to have but one sense, touch, or a general sensibility, — it receives but one kind of sense impression from influences which higher animals recognize as diverse, — while higher animals may distinguish two or more kinds of impression, and so on. It should be noticed that the common division of senses into touch, taste, smell, sight, and hearing is somewhat arbitrary, even man not being always able to discriminate, for instance, between taste and smell, while certain sensations are recognized, such as perception of temperature and of pain, which do not strictly belong to any of the "five senses" so called.

Suggestions regarding the Practical Work

The amount of illustrative experimental work in physiology that can be done in a high school depends chiefly upon two factors: the material equipment of the school and the tact of the teacher.

Vivisection doubtless has its place, but not in the public schools. Ordinary dissections sensibly performed can be made a successful part of class work in most of our high schools, but occasionally deference to public opinion will require that the dissections be performed only by the teacher, or possibly not at all.

No attempt is made in this book to give detailed directions for dissecting, nor for the preparation of material for study with the compound microscope. It is assumed that a teacher of advanced physiology has received some preliminary training in anatomy and microscopical methods. If so, then suggestions will be far better than specific directions.

It is not expected that all the experiments will be performed by a class. When a compound microscope is not available, some of the exercises must necessarily be omitted. It is believed, however, that all the demonstrations, dissections, and experiments can be performed in any school of moderate equipment. A great mistake is made when much apparatus is interposed between the student of elementary science and the objects of his study. The teacher should make sure that the illustration is not substituted for the idea that it is intended to explain. In some instances conditions will require that the teacher perform most of the work of an experiment, but as far as possible the pupil should himself be responsible for each detail.

Demonstrations and Experiments[1]

1. *Amœba.* — The amœba is not always easily obtained. If débris of water plants be kept in shallow dishes of water for several days, there can usually be found specimens of amœba in the scum that forms on the surface of the water, or in the ooze that collects at the edges and bottoms of the dishes. On mounting some of the material on a glass slide and examining with the compound microscope, there may be seen small, irregular, transparent masses of a jellylike nature moving along very slowly with a rolling or flowing motion (Fig. 3). Attention should be given to the constantly changing form of the animal, which thus exhibits a fundamental characteristic of protoplasm, *instability.* If, when an amœba is fully extended, sending out processes, *pseudopodia,* from the main part of the body, the slide be gently tapped, the animal will be seen to contract quickly into a rounded mass, showing another characteristic of protoplasm, *irritability,* or the capacity of response to stimulus.

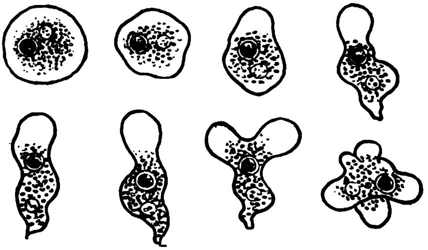


Fig. 3. — Amœba in eight successive stages of movement.

2. *White Blood Corpuscles.* — If a drop of fresh human blood, or preferably of frog's blood, be mounted on a glass slide and examined with the compound microscope, among the numerous red corpuscles may be seen a few transparent ones (Fig. 4). On remaining undisturbed for some time they change in shape, or even migrate, in a manner similar

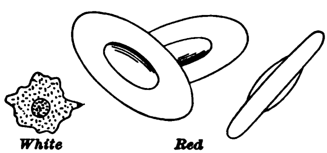


Fig. 4. — Blood cells (corpuscles) of frog.

[1] *Note to Teachers.* — The demonstrations and experiments should precede the recitation of the lessons which they illustrate. The pupil should not be required to describe the brain, for example, until he has studied the dissected organ itself.

to that of the amœba. Fresh blood may be obtained by pricking the finger with a sterilized needle, and by decapitating or pithing a frog.

3. *Movements of Protoplasm in Plants.* — The phenomena of protoplasmic movements can be observed in a variety of plants. The Stoneworts, *Chara* and *Nitella*, and the stamen hairs of the Spiderwort, *Tradescantia*, furnish some of the best examples. In all these the protoplasm is inclosed in a cell wall, and when observed with the compound microscope is seen to exhibit streaming movements and circulation of particles in the contents of the cell. The response of protoplasm to changes in temperature can be very easily shown by placing the slide on a warming stage upon the microscope stand as shown in Fig. 5. When the warming stage is heated, the protoplasmic movements are seen to increase in rapidity up to a certain point. As it cools, the movements become slower.

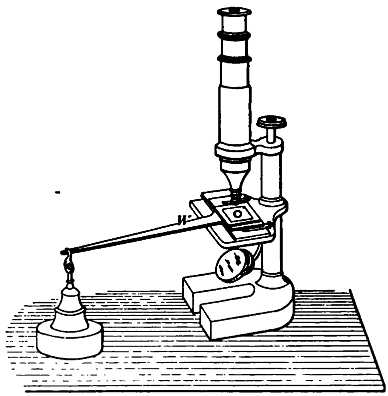


Fig. 5. — Compound microscope with simple warming stage (*W*) attached.

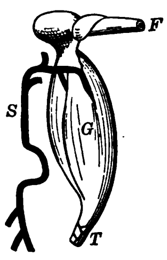


Fig. 6. — Nerve-muscle preparation.

F femur.
G gastrocnemius muscle.
S sciatic nerve.
T tendon (*tendo Achilles*).

4. *Properties of Protoplasm in Muscle.* — In some animals the various tissues retain their vitality and properties for a considerable time after the death of the individual animal. The common frog furnishes us one of the best examples of this. If a frog's gastrocnemius muscle with sciatic nerve attachments (Fig. 6) be dissected out (see Figs. 7 and 8) shortly after decapitation of the animal, it will retain its properties for a considerable length of time, if kept well moistened with normal salt solution (0.75 per cent solution of common salt). If the nerve be cut with sharp scissors a contraction of the muscle occurs. Touching the nerve with a red-hot needle produces a similar contraction

in the muscle. Placing the fresh-cut end of the nerve in a saturated solution of common salt brings about a series of contractions in the muscle. The muscle also contracts when the nerve is stimulated with a weak electric current. If the nerve muscle preparation be placed on a copper plate, and the temperature of the latter be raised above or lowered below the normal, there will occur variations in the response of the muscle to stimuli. (Electrical stimulation will be found most convenient.) The relation of muscular action to temperature will thus be strikingly represented. These experiments with the nerve-muscle preparation show that the living substance is *irritable*, *unstable*, and *conductive* of stimuli.

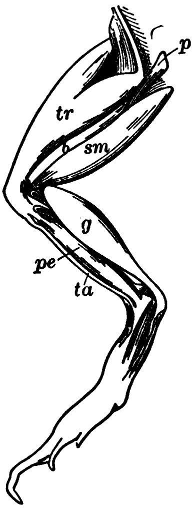


Fig. 7.

Fig. 8.

Muscles of the left leg of the frog. Fig. 8 shows distribution of the sciatic nerve.

ad	M. adductor magnus.	*sc*	sciatic nerve.
b	M. biceps.	*sm*	M. semimembranosus.
g	M. gastrocnemius.	*st*	M. semitendinosus.
p	M. pyriformis.	*ta*	M. tibialis anticus.
pe	M. peroneus.	*tr*	M. triceps.
ri	M. rectus internus minor.		

5. *Cells.* — The amœba and the white blood corpuscles already studied furnish very good examples of cells which have no fixed form nor definite shapes. The red blood corpuscles of the frog are cells in which the nucleus can be easily discerned by aid of the microscope (Fig. 4, p. 16).

CHAPTER II

TISSUES AND ORGANS

10. The human body, beginning as a single cell, is gradually built up by a process of division and subdivision of that cell, so that the complete, adult man is but a mass of cells with some cementive and connective matter. It is found, however, that differences early appear in the characteristics of different cells, and these differences increase as development proceeds. *A group of similar cells having a similar function is called a tissue.*

11. Differentiation of Tissues. — In the lowest animals, composed of but a single cell, all the different parts of the body are essentially alike (leaving the nucleus out of consideration) and have the same functions. One part may move as well as another. All parts share in the process of nutrition, and one part responds as well as another to stimulus. But the higher animals are found to be made up of unlike parts, which minister in different ways to the life of the whole being. As the cells multiply, certain groups of cells become changed in such a manner as to adapt them to the performance of some special function, while other parts are adapted to other functions. A number of cells lying together become modified so as to make up a tissue adapted to a certain purpose. Other cells become modified in a different way to form a tissue adapted to a different

purpose, and the whole body becomes a mass of many different tissues, each having its definite and special characteristics and structure. This process is known as *differentiation of the tissues*, and is accompanied by what is called *physiological division of labor*. One tissue is better adapted to the performance of a certain office in the body than are others, and that special work is given it to do, so that the work of carrying on the operations of the body is divided up among the tissues.

12. Organs. — A living being is often called an *organism*. In order to secure the greatest efficiency in their labors, the various tissues are built up into a multitude of mechanisms called *organs;* for example, the eye, the hand, the liver. Several different kinds of tissue often enter into the structure of a single organ, and the same sort of tissue appears in many different organs.

A number of organs so arranged and related to one another as to coöperate in carrying on a special process or series of processes, is called a *system*, — as the digestive system, or the nervous system.

13. Classification of Tissues. — Tissues are variously classified by different authors, but one broad distinction may be noted which divides them into two great classes: (1) The tissues which have to do with the setting free of energy. These are the muscular and nervous tissues. (2) The tissues which have to do with renewing the substances and restoring the power of responding to stimulus. In this second class are grouped all the remaining parts of the body, which include tissues differing widely from one another — from the solid, *bony tissue* of the skeleton, and the still harder *enamel* which covers the teeth, to the soft substance composing the brain, the elastic fat which rounds out the figure, and the fluid which we call *blood*.

14. The following table shows this classification : —

1. Tissues which have to do with liberating energy — Master Tissues
   - Muscular
   - Nervous
2. Tissues which have to do with the protection, support, and renewal of the Master Tissues
   - Epithelial Tissues
     - Simple Epithelium
       - *a.* Pavement
       - *b.* Cubical, Spheroidal, and Columnar
       - *c.* Ciliated
     - Compound Epithelium
       - Transitional
       - Stratified
         - Columnar
         - Ciliated
         - Squamous or Scaly
   - Connective Tissues
     - Areolar
     - Fibrous....
       - *a.* White
       - *b.* Yellow or Elastic
     - Adipose
     - Cartilage
     - Bone
     - Blood

15. The Master Tissues. — *Muscular tissue* liberates energy which takes the form of motion attended by some measure of heat. But the changes in muscular tissue by which energy is liberated are guided, regulated, and adapted to the purposes of human life by means of *nervous tissue;* that is, the muscles are the instrument, but an instrument motionless and useless until the nerves supply the impulse which sets the muscles at work. A muscle develops energy under the action of nervous stimulus conveyed to the muscle cell through nervous tissue. Energy is set free in nervous tissue when the nervous organ is *stimulated* by the influence adapted to it. The nerves carry the impulse to the muscle, and energy is liberated as motion and heat. Muscular and nervous tissues possess *irritability*, that is, they respond to *stimulus*, in

the one case by contraction, in the other by some change not yet understood, giving rise to what is called a "nervous impulse," and in the act they develop energy by the breaking down of their own substance. Unless that substance is renewed the tissue will cease to respond to stimulus, — will die. The remaining tissues of the body, therefore, are engaged in one way or another in preparing the needful food, in conveying it to these "master tissues," in taking up the waste substances produced in the evolution of energy and preparing them for removal from the body, or in furnishing mechanical support to the body and its various parts. In these processes are involved all the parts which are concerned in digestion, respiration, circulation, and excretion. This varied and complex series of operations implies a vast array of muscular movements, and all are governed by the nervous system under the action of its varied stimuli.

16. Epithelial Tissues. — The free surfaces of the body, both within and without, are covered with a tissue called *epithelium*. *Simple epithelium* is composed of but one layer of cells, arranged like flat paving stones and fitted together with a very little cementing material (Fig. 9, *A*). The epithelium of this variety found lining the interior of the blood vessels, and some other surfaces which are not exposed to the outer air, is called *endothelium*.

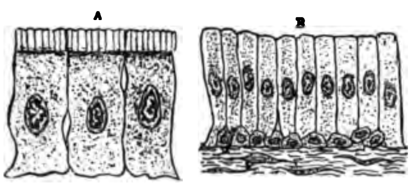


Fig. 9. — Columnar epithelium.
A simple. *B* stratified.

The *cubical*, *spheroidal*, and *columnar* epithelial tissues are named from the shape of their cells. In *ciliated*

epithelium each of the cells is surmounted by tapering, hairlike filaments (Fig. 10).

Fig. 10. — Ciliated epithelium from a small bronchial tube.

Compound epithelium is composed of more than one layer of cells (Fig. 11). Epithelium contains no blood vessels, but is nourished by lymph. It forms the external layer of the skin and the mucous membrane.

17. Connective Tissues exist in many diverse forms, but all are alike in origin, being developed from the same layer of the embryo; alike in structure, having a large amount of intercellular material; and alike in function, being devoted to supporting and connecting the master tissues.

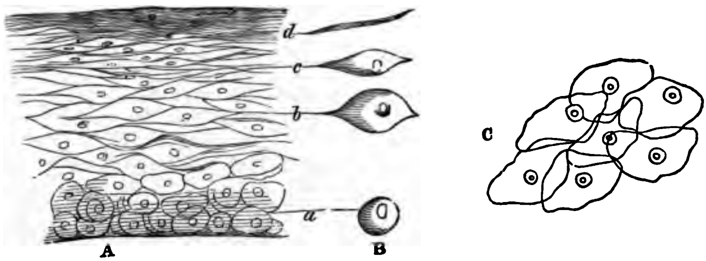


Fig. 11. — **Compound stratified epithelium.**

A vertical section of the skin. *B* lateral view of the cells.
C flat side of scales like *d*, magnified 250 diameters, showing the nucleated cells transformed into broad scales.

Areolar tissue is made up of cells, white and yellow fibers, and some intercellular matter (Fig. 12). It is found widely distributed through the body, appearing as delicate, elastic, sheathing membrane for muscles, nerves, glands, and other organs. It penetrates into the substance of the organs and connects and supports their various parts.

White fibrous tissue is found in ligaments and tendons, the tough lining membranes of bones, brain, etc. (Fig. 13, *A*). It is composed mainly of bundles of strong, white fibers containing nucleated cells.

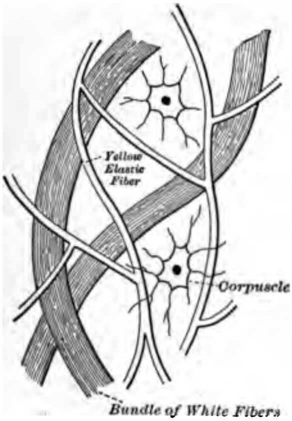


Fig. 12.—Diagram of areolar tissue.

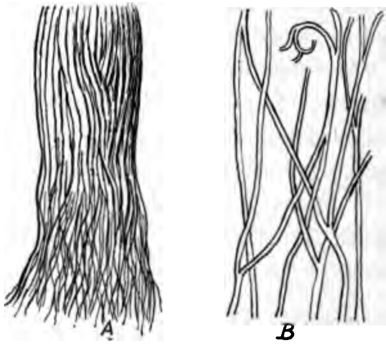


Fig. 13.—Fibrous tissue.
A white fibrous tissue.
B elastic or yellow fibrous tissue.

Elastic or *yellow fibrous tissue* contains yellow, elastic fibers (Fig. 13, *B*) bound into bundles by areolar tissue. It appears in some ligaments, and in the walls of the arteries, and in the air cells of the lungs.

Adipose tissue is the fat of the body, and is found in nearly all parts, usually in connection with areolar tissue. Adipose tissue consists of protoplasmic cell walls filled with liquid fat.

18. Cartilage appears in two forms,—*hyaline cartilage* (Fig. 14) and *fibrocartilage* (Fig. 15), the first being clear and free from fibers, the second composed largely of white or yellow fibers. Cells are found in all kinds of cartilage, but there is always a proportionately large amount of intercellular matter which is produced by the cells.

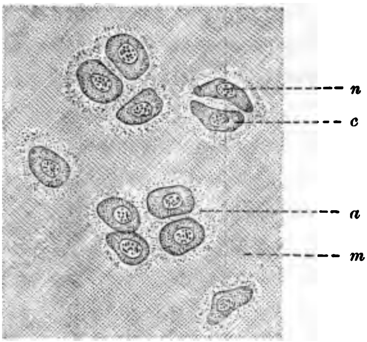


Fig. 14. — Hyaline cartilage.

a group of four cartilage cells.
c a cell. *n* nucleus.
m matrix.

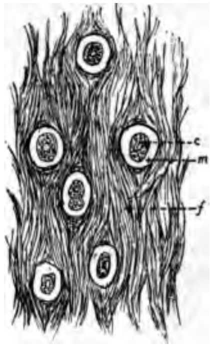


Fig. 15. — Fibrocartilage.

c cartilage cells surrounded by hyaline matrix (*m*).
f fibrous tissue.

19. Bone is more solid than the other tissues. It is penetrated throughout by minute canals, called ***Haversian canals***, containing blood vessels (Fig. 16). The final

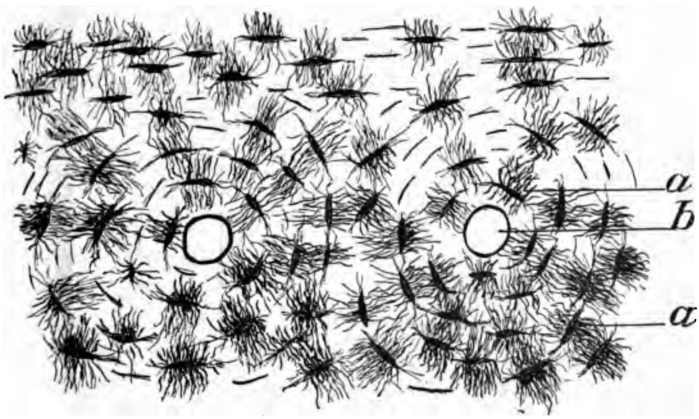


Fig. 16. — Cross section of bone.

a lacunæ, spaces in living bone occupied by bone cells.
b Haversian canal.

structure of bone is fibrous, and along with the fibers are cells called *bone corpuscles*, while the cementing material is earthy matter. In many situations, parts which are in early life composed of cartilage become afterward replaced by bone, through the process called *ossification*.

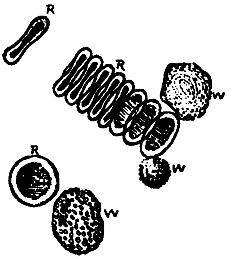


Fig. 17. — Human blood corpuscles.
R red. *W* white.

20. Blood is a fluid connective tissue which conveys nutriment to all parts of the body (Fig. 17). It holds suspended in its liquid portion, or *plasma*, large numbers of cells called *corpuscles*. These are of two sorts, named from their color the *red* or *colored* corpuscles, and the *white* or *colorless* corpuscles. The latter have one or more nuclei, while the red corpuscles have none.

CHAPTER III

A GENERAL VIEW OF THE NERVOUS SYSTEM

21. The great distinguishing feature separating man as an animal from all other animals is, as we have seen, his possession of a nervous system of more complex and intricate structure than any other in the animal kingdom. It is now fully recognized that the nervous system is the central, unifying, coördinating element in the human organism — that for which all other parts exist and to which all are subordinate. In order, therefore, to understand clearly the part which each portion of the body is designed to play in the general plan, it is necessary to have some general knowledge of the nervous system, while a fuller study of its parts and their functions may be postponed to a later period.

22. Divisions of the Nervous System. — Physiologists have been accustomed to describe two great divisions of the nervous system, called the *central* or *cerebro-spinal system*, and the *ganglionic* or *sympathetic system*, the first having control of sensation and voluntary motion, the second presiding over those vital operations not under voluntary control, its nerves being in general distributed to the internal organs and the blood vessels. It has, however, long been understood that there are not two nervous systems, but one. Still, as a matter of convenience in description, the well-known terms are generally

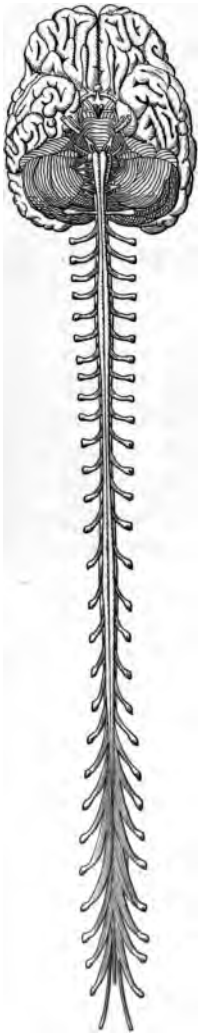


Fig. 18.—**Brain and spinal cord, ventral (anterior) view.**

retained, and the nervous system is treated under its twofold aspect.

23. The Cerebro-spinal System is composed of the brain and the spinal cord, with the nerves passing from them to the various parts of the body (see Fig. 1, p. 8, and Fig. 18).

24. The Brain fills the cavity of the skull. It consists of five principal parts: (1) the *cerebrum;* (2) the *optic thalami*, which are so closely united to the cerebrum as to seem to be a part of it; (3) the *optic lobes*, or *corpora quadrigemina*, and *crura cerebri;* (4) the *cerebellum*, and with it the *pons Varolii;* (5) the *medulla oblongata* (Figs. 19 and 20). Looked at from above or from the side, the only parts of the brain that appear are the cerebrum, a part of the cerebellum, and part of the medulla oblongata.

25. Cranial Nerves. — From the under surface of the brain arise twelve pairs of nerves (Fig. 19), which pass through openings in the cranial bones and are distributed in a manner to be described hereafter. They are of three classes: (1) Nerves of special sensation; (2) motor nerves, that is, nerves which carry nervous impulses to the muscles and cause them to contract; and (3) mixed nerves, that is, both sensory and motor.

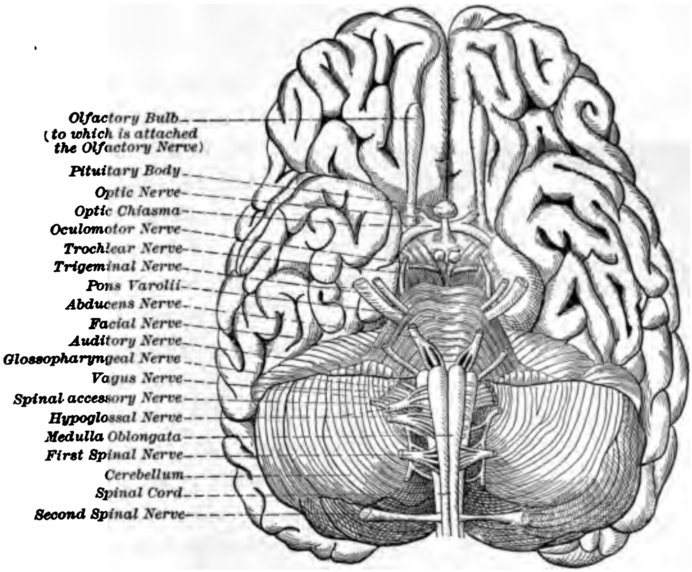


Fig. 19.—**Ventral (anterior) surface of the brain.**

26. The Spinal Cord and Spinal Nerves. — The spinal cord is a column of soft nervous matter, filling the long channel in the spinal column (Fig. 18). Thirty-one pairs of nerves arise from the spinal cord, each having two roots, — a posterior and an anterior root (Fig. 21). Upon the posterior root, just before it unites with the anterior root, is a little knot of nervous matter called a *spinal*

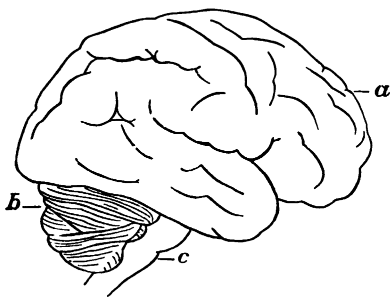


Fig. 20.—**Side view of brain.**
a cerebrum. *b* cerebellum.
c medulla oblongata.

ganglion. The anterior roots of spinal nerves contain what are called *efferent* nerve fibers, that is, fibers carrying impulses *from* the nerve center. These are sometimes called *motor* nerve fibers, because their stimulation usually results in motion; but the term is not strictly accurate, since other than motor impulses may pass over efferent nerves. Posterior roots contain *afferent* nerve fibers, that is, fibers carrying impulses *toward* the nerve center. They are also called *sensory* nerve fibers, because when they are stimulated feeling or sensation most often results, but other impulses than sensory ones may be conveyed by them.

Fig. 21.—Diagram of cross section of spinal cord, showing nerve roots.

P posterior root of spinal nerve. *G* ganglion. *A* anterior root. *S* spinal nerve.

27. The Sympathetic System consists of a chain of *ganglia* lying on each side and in front of the spinal column, of three main *plexuses* (or nerve networks) in the cavities of the chest and abdomen, of many small ganglia in all parts of the body, and of an immense number of fine nerve fibers (Fig. 22). Each ganglion of the chain is connected by nerve fibers with the one above and the one below, as well as with the spinal cord. In general, the number of pairs of ganglia corresponds to the number of vertebræ, or segments of the backbone; but there are only three pairs of ganglia in the neck, and in front of the coccyx, or last segment of the backbone, there is only a single ganglion.

28. Gray and White Nervous Matter.—Two kinds of nervous matter, easily distinguished by their color, are found in the body. In the cerebrum and the cerebellum the gray matter is mainly in the surface layer, called the *cortex*, the deeper portions being of white matter; while in

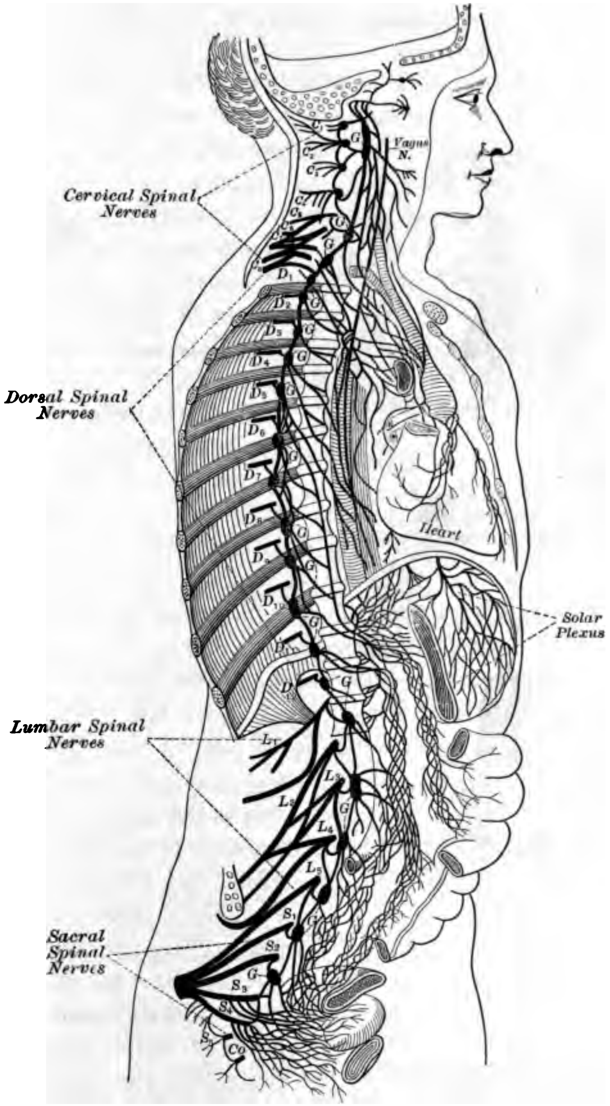


Fig. 22. — Diagram of the sympathetic nervous system.

G ganglion chain. *Co* coccygeal spinal nerve.

the spinal cord the reverse is the case, a central column of gray matter being surrounded by white matter (Figs. 23 and 24). The ganglia are composed almost wholly of gray matter.

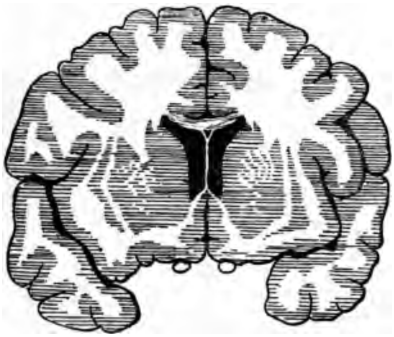


Fig. 23.—Cross section of the hemispheres of the brain, showing arrangement of gray and white matter.

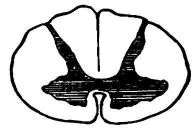


Fig. 24.—Cross section of spinal cord, showing arrangement of gray and white matter.

29. Nerve Cells.—Gray nervous matter is made up mainly of *nerve cells* (Fig. 25). These vary much in size and shape. Each sends out one or more branches, or processes, one of which forms the central core of a nerve fiber and is called the *axis cylinder process*. A ganglion is a collection of nerve cells imbedded in nerve fibers.

30. Nerve Fibers.—Every nerve fiber has connection with at least one nerve cell, for its central strand, called the *axis cylinder*, is always the axis cylinder process of a nerve cell (Fig. 26). This is the essential, indispensable part of the nerve fiber. Surrounding the axis cylinder there is usually a layer of white, oily matter called the *medullary sheath*, and outside of that is a thin inclosing membrane called the *neurilemma*.

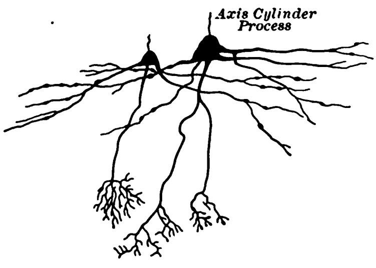


Fig. 25.—Nerve cells (mitral) from the olfactory bulb.

The last is continuous for the whole length of the fiber, but the medullary sheath is broken at short intervals by little spaces called nodes. Some fibers have only the neurilemma, and are therefore gray in color; for it is the medullary sheath which gives the characteristic shining white appearance to nerves and nerve fibers. Those fibers possessing the sheath are called *medullated nerve fibers;* those without it are called *nonmedullated.*

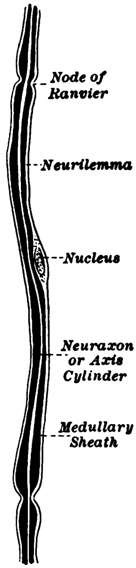


Fig. 26. — Portion of a medullated nerve fiber.

Demonstrations

6. *The Brain.* — The brain of the sheep will be found to be very satisfactory in demonstrating to a class the general structure of this portion of the central nervous system. The brain of the cat, dog, or ox may be used instead. The brain can be removed from the skull by sawing away the roof of the latter and with a scalpel cutting the attaching membranes and nerves. The brain should be prepared some days, or even weeks, before it is needed by the class, and hardened and preserved in some suitable medium. Strong alcohol, a 2 to 5 per cent solution of formalin (formol) in water, and a 2 to 5 per cent solution of bichromate of potash are very good hardening and preserving reagents. But more satisfactory is the following mixture: 95 per cent alcohol, six parts; 2 per cent solution of formalin, four parts. When specimens are preserved in a fluid containing formalin, they should be soaked in water a short time before using, to avoid the irritating effects of formalin vapor on the eyes, etc. Where possible, each student should be provided with one of the preserved specimens. A brain recently removed should be at hand, but it will be found to be too soft for much careful study. With care one preserved brain may be made to suffice for an entire class. After examination the specimens may be preserved for more detailed study later on. In studying the brain follow the descriptions of the general text.

7. *The Spinal Cord.*—Procure at a slaughterhouse a spinal cord of an ox and examine it fresh, or preserve it in one of the fluids mentioned in the preceding section. Preserved portions can be used later in a more careful study of the structure of the cord.

8. *The Sympathetic Nervous System.*—If the abdominal cavity of a dog, cat, rat, or frog be opened and the viscera displaced, there may be seen on each side of the backbone a white cord with grayish enlargements, ganglia. The two cords and their ganglia constitute the main chains of the sympathetic system.

9. *Nerve Fibers.*—Tease out with needles in water on a glass slide a small piece of a nerve. Even without the aid of a lens the nerve is seen to be composed of small, threadlike fibers. Examined with the compound microscope the fibrous structure will become more apparent.

PART II

CONSCIOUS NERVOUS OPERATIONS: MOTION AND SENSATION

Of many of the processes which have to do with man's life he is wholly or partly unconscious. The wonderful operations of growth and development go on chiefly without his knowledge. The nerve cells which order and direct all the vital activities carry on their work so silently, so regularly, so skillfully — without jar or confusion — that neighboring cells may not even know that they are busy.

Of other nervous activities a man is fully conscious, and without his consciousness the object of those operations is not accomplished. A large part of the nervous system and a large part of the other tissues and organs of the body have for their chief business the production of conscious *motion*. Other sets of nerves, nerve cells, and special organs are employed in bringing about those experiences called *sensations*. These two objects are effected through what may be called *conscious nervous operations: motion* being the result of the action of certain nervous impulses upon bones and muscles; *sensation*, the result of the action of other nervous impulses upon the special organs for sensation.

In order to understand these conscious nervous operations it is necessary to study the skeleton and joints, the muscular system, the skin as a sense organ, the senses of taste, smell, sight, and hearing, and the apparatus for speech.

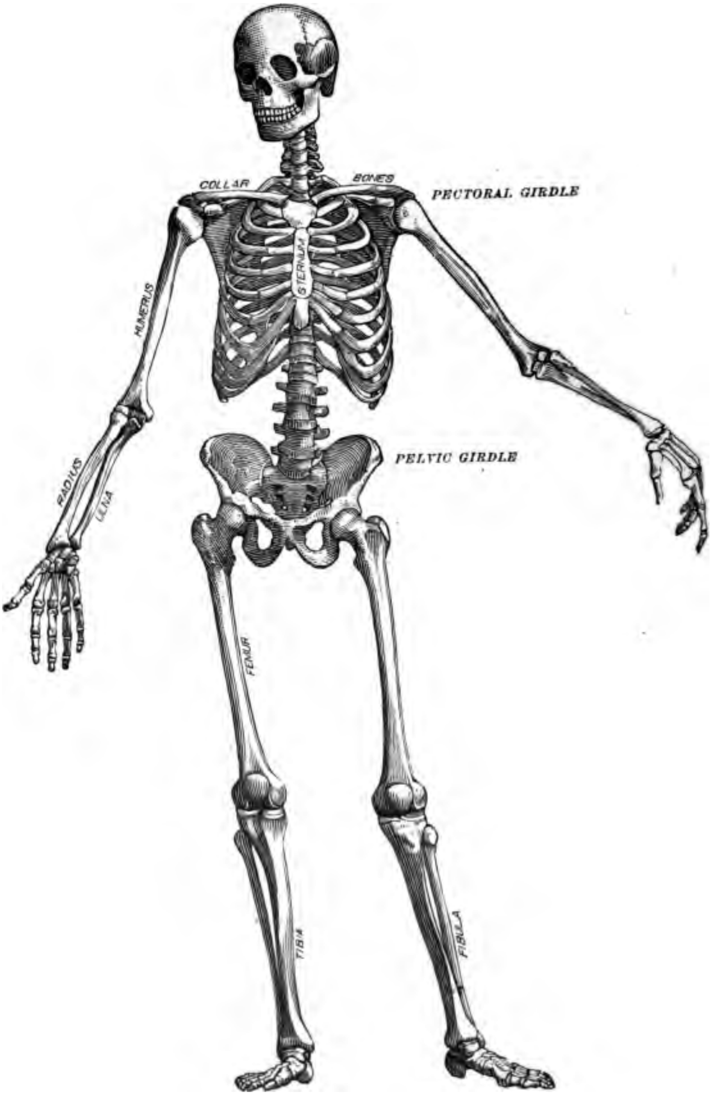


Fig. 27. — The skeleton.

CHAPTER IV

THE FRAMEWORK OF THE BODY, OR THE OSSEOUS SYSTEM

31. Functions of the Bones. — Certain parts of an animal body are more essential to its existence than others, and more important to its well-being. These portions are of especial delicacy in substance and structure, and peculiarly liable to injury. They therefore require protection. For this purpose the more solid substances which make up the body are arranged to inclose or shield the softer and more delicate parts.

In one large group of animal forms, called invertebrates, which includes insects, mollusks, crabs, lobsters, etc., the outer portion of the body consists usually of a more or less hard and tough crust called the *exoskeleton*, which covers the softer parts. But the higher group of animals, called vertebrates or backboned animals, to which man belongs, possess an inner, bony framework, called the *endoskeleton*, so arranged as to form a support and a defense to the more sensitive and more essential parts.

In all vertebrates the skeleton consists of a somewhat firm but flexible bony column to which are attached the bones of the head, the ribs, and the pectoral and pelvic girdles, which connect respectively the upper and the lower limbs with the trunk (Fig. 27).

The bones of the skeleton furnish the necessary levers and points of support for the muscles which are the organs of motion.

32. Provision for Movement in Different Classes of Animals. — A distinguishing feature of the animal kingdom is the power of voluntary motion, and the ability at some period of life to move about from place to place. For this purpose the different classes and orders of animals are provided with a great variety of mechanical devices. Certain aquatic creatures propel themselves by means of pulsations in the whole body. Snakes and worms swim by the undulations of the body. The squid fills a certain cavity within itself with water and then suddenly expels it, and the force of the ejection moves the body in one direction or another, according to the direction of the current of water ejected. The jellyfish propels itself by drawing in and expelling water from its bell-shaped body. Animalcules move themselves by the rapid vibrations of innumerable hairlike projections. But all the higher forms of animals move by means of muscles and ligaments attached to an internal solid framework, or skeleton.

33. The Vertebrate Skeleton. — A careful study of any vertebrate skeleton discloses marvelous adaptations for accomplishing the two main objects of protection and motion. Protection to the vital parts might have been secured by means of a rigid, unyielding case, but in order to allow motion in all parts of the body also, the skeleton is composed of many separate pieces united together by elastic tissues. The whole number of bones in the adult man is about 206, while in the child the number is yet larger, because, as a child grows older, certain bones which are at first distinct (and remain so in the lower animals) grow together to form one. For convenience in study, the bony framework is divided into two parts called the *axial skeleton* and the *appendicular skeleton.*

34. Axial Skeleton. — The bones of the head, neck, and trunk compose the *axial skeleton.*

35. The Skull. — At the upper extremity of the vertebral column appears the *skull* (Fig. 28), composed of (1) the *cranium*, the strong casket which incloses the most precious part of the animal structure, — the brain — and (2) the various bones forming the *skeleton of the face.*

Fig. 28. — The skull.

1 frontal bone.
2 parietal bone.
3 temporal bone.
4 sphenoid bone.
5 ethmoid bone.
6 occipital bone.
7 superior maxillary (upper jaw) bone.
8 malar bone.
9 lachrymal bone.
10 nasal bone.
11 inferior maxillary (lower jaw) bone.

36. The Cranium. — In the adult the cranium consists of eight bones, each composed of two firm, compact plates with a spongy layer between. The bones which form the arch of the head are closely joined together by irregularly notched edges, the lines of union being called *sutures.*

The cranial bones are named as follows: 1. The *frontal bone*, forming the front of the skull and of especial solidity and thickness, as most exposed to injury. 2. The *parietal bones*, a pair of thin, flat bones meeting along the top of the head. 3. The *temporal bones*, below the *parietal*

on each side, and having large openings leading into the ear cavities. 4. The *sphenoid*, forming part of the floor of the brain cavity. 5. The *ethmoid*, forming part of the floor in front and joined to many of the facial bones. It is perforated for the passage of the olfactory nerves. 6. The *occipital*, a large bone at the back of the head and also a part of the floor of the skull. It is perforated by small holes through which pass nerves, and by a large opening called the *foramen magnum* for the passage of the spinal cord to its union with the brain.

37. The Facial Skeleton consists of fourteen bones: 7. The *superior maxillary bones*, or upper jaw bones, carrying the upper teeth and forming most of the hard palate. 8. The *malar bones*, or cheek bones. 9. The *lachrymal bones*, near the inner angle of the socket of the eye, and perforated for the tear ducts. 10. The *nasal bones*, forming the roof of the nose. 11. The *inferior maxillary* or lower jaw bone. 12. The *inferior turbinate bones*, one in each nostril chamber. 13. The *vomer*, forming part of the partition between the nostrils. 14. The *palate bones*, which complete the skeleton of the hard palate.

38. The Hyoid.— A small U-shaped bone secured by long ligaments to the base of the skull and lying in the neck at the root of the tongue, is called the *hyoid bone* (Figs. 79, 80, and 82, pp. 136, 138). It furnishes points of attachment for many muscles.

39. Bones of the Ear. — Three minute bones in the middle ear (Figs. 74 and 75), the *malleus*, the *incus*, and the *stapes*, have to do with the conduction of sound.

40. The Vertebral Column. — In a man of average stature the spinal column is about twenty-eight inches in length. It consists of twenty-six separate bones (Fig. 29). The upper part, which includes more than half the whole

length of the column, is made up of twenty-four separate bones, each called a *vertebra.*

Of these the first or upper seven lie in the neck and are called *cervical vertebræ.*

The next twelve bones of the spinal column are those to which the ribs are attached. They are called the *thoracic* or *dorsal vertebræ.*

Next come the *lumbar vertebræ,* which are larger than any other of the movable vertebræ. They support no ribs, but receive many large and strong muscles.

Below these is seen the *sacrum,* composed in the infant of five vertebræ, which in the adult become one bone. To the broad spaces on its sides are attached the bones of the *pelvic arch* which

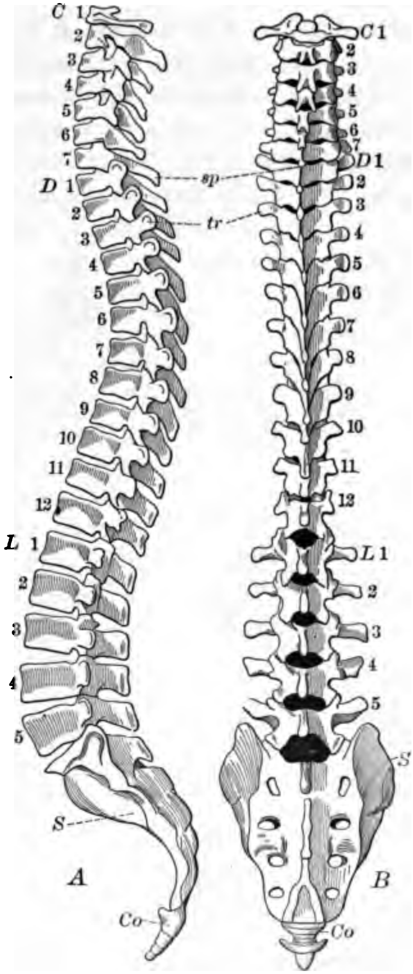


Fig. 29.—The vertebral column as seen from left side (*A*) and from behind (*B*).

C 1-7, *D* 1-12, *L* 1-5 cervical, dorsal, and lumbar vertebræ.

S sacrum. *sp* spinous process.

Co coccyx. *tr* transverse process.

supports the lower limbs. It has eight openings, which communicate with the canal inclosing the spinal cord and permit the passage of spinal nerves.

At the lower end of the spinal column is the coccyx, formed by the union of four very small vertebræ into one bone. It is that part of the skeleton which in the lower vertebrate animals forms the tail.

41. The Vertebræ vary somewhat in form, but are all constructed upon the same general plan (Fig. 30). There is a stout bony cylinder, called the *body*, or *centrum*. To this solid centrum is attached an arch, called the *neural arch*, which forms, with the back of the centrum, an inclosed space named the *neural ring*. The successive neural rings form in the spinal column a long tube in which the spinal cord may safely lie.

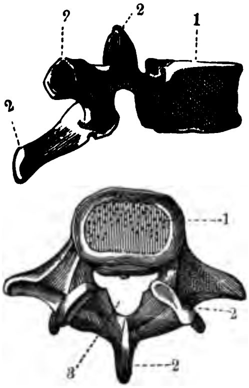


Fig. 30. — A dorsal vertebra shown in two positions.

1 centrum. 2 processes. 3 neural ring.

From the back of the neural arch extends a long bony projection called the *spinous process*, and the successive processes, or spines (Fig. 29), extending down the backbone, give to it the name of *spinal column*. Six other processes project from each vertebra: one on each side called *transverse processes;* two called *anterior articular processes*, extending forward; and two called *posterior articular processes*, extending backward, to meet the corresponding processes of the neighboring vertebræ. These processes form, by means of the intervening cushion of cartilage and connecting ligaments, a joint permitting a slight amount of motion.

Two shallow depressions in the forward portion of the centrum of each of the dorsal vertebræ, with corresponding depressions in the adjoining vertebra, form pits which receive the *heads* of the ribs. Similar depressions at the ends of the transverse processes of the dorsal vertebræ assist in securing the ribs to the spine (Fig. 31).

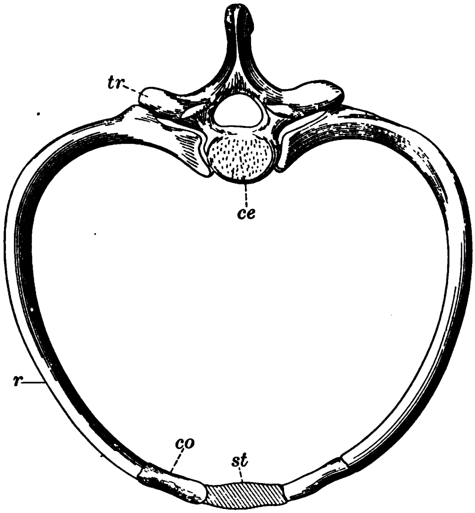


Fig. 31.—Articulation of a pair of ribs to a vertebra.

ce centrum of the vertebra. *r* rib.
tr transverse process. *co* costal cartilage.
st sternum.

Between each two adjoining vertebræ are elastic cushions of *fibrocartilage*, which assist in providing for motion and flexibility in the spinal column and in preventing injurious jarring of the brain and spinal cord.

42. The Atlas and Axis.—The first two cervical vertebræ have certain modifications of structure for the sake of the freer motion needful in the neck. The *atlas* or *first*

two pairs have their front cartilage ends unattached, and are therefore called *floating ribs*. All the ribs have a downward slope, their front ends being lower than the hinder ones. This permits of a considerable enlargement in the size of the cavity of the *thorax*, or chest, when, by the contraction of the muscles of the chest, the front ends of the ribs are raised. The object of this will be shown later.

45. The Sternum, or breastbone (Figs. 27 and 33), supports the forward ends of the ribs (with the exception of the two lowest, or floating ribs) by means of the costal cartilages, which give more freedom of movement than would be possible were the bones solid to the end. The sternum is composed, in the adult, of three pieces, the lowest being of cartilage.

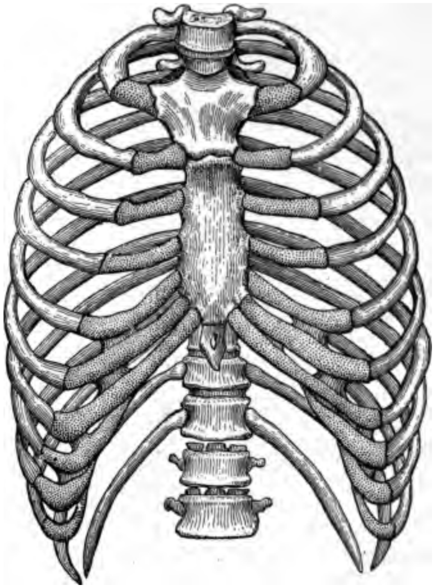


Fig. 33. — Skeleton of thorax, showing ribs, costal cartilages, sternum, and some of the thoracic vertebræ.

46. The Appendicular Skeleton is composed of the *pectoral girdle*, the *pelvic girdle*, and the bones of the limbs.

47. The Pectoral Girdle (Fig. 27) consists of four bones, two on each side, — the *scapula* and the *clavicle*. The *scapula*, or shoulder blade, is a triangular, nearly flat bone lying at the back of the shoulder and not attached

directly to the spinal column. It has a shallow pit at one of the upper corners for the end of the *humerus*, or upper arm bone, and a projection to which the other bone of the arch, the clavicle, or collar bone, is secured. The *clavicle* is a round, slender bone, attached by its two ends to the scapula and the sternum.

48. The Upper Limbs contain, each, thirty bones. They are the *humerus*, or upper arm bone; the *radius* and *ulna*, side by side in the lower arm; the eight small bones of the *carpus*, or wrist; the five cylindrical bones of the *metacarpus*, or palm of the hand; and the *phalanges*, or finger bones, fourteen in number, two being in the thumb and three in each other finger.

49. The Pelvic Girdle (Fig. 27) is formed by one large spreading bone on each side, called the *os innominatum*, or hip bone. On the outer side is a deep socket for the head of the *femur*. The hip bones are made to support great weight and to resist severe shocks. They sustain the whole pressure of the trunk and of burdens carried, and also receive the force of the various movements of the lower limbs, as in running, jumping, cycling, etc.

50. The Lower Limbs are similar in structure to the upper. The *femur*, or thigh bone, the largest bone in the body, corresponds to the humerus; the *tibia* and *fibula*, to the radius and ulna. In the ankle are seven *tarsal bones*, and in the arch of the foot five *metatarsals*, to which are added the fourteen *phalanges*, or bones of the toes. There is, besides, a bony disk, imbedded in the great ligament over the knee, forming a protection to the knee-joint, and called the *patella*, or kneepan.

51. Observe the provisions in the human skeleton for securing firmness and strength to the upright figure. It has been found that the arch is the strongest form of

structure for a given amount of material. The shoulder arch of the skeleton furnishes support to the arms so strong that those limbs may be used to lift great weights and hurl them through the air, and to perform a great variety of labors. The pelvic arch and the arches of the foot are also designed to support securely the tall human figure and to carry heavy loads.

52. Table of the Bones.—

(A) AXIAL SKELETON

1. Skull, 28	Cranium, 8	Frontal	1
		Parietal	2
		Temporal	2
		Occipital	1
		Sphenoid	1
		Ethmoid	1
	Face, 14	Superior Maxillary	2
		Inferior Maxillary	1
		Palate	2
		Nasal	2
		Vomer	1
		Inferior Turbinate	2
		Lachrymal	2
		Malar	2
	Bones of Ear, 6	Malleus	2
		Incus	2
		Stapes	2
2. Hyoid, 1			1
3. Spinal Column, 26		Cervical Vertebræ	7
		Dorsal Vertebræ	12
		Lumbar Vertebræ	5
		Sacrum	1
		Coccyx	1
4. Thorax, 25		Ribs	24
		Sternum	1

(*B*) Appendicular Skeleton

1. Shoulder Girdle, 4	Clavicle	
	Scapula	2
2. Upper Extremities, 60	Humerus	
	Ulna	2
	Radius	2
	Carpals	16
	Metacarpals	10
	Phalanges	28
3. Pelvic Girdle, 2	Os Innominatum	2
4. Lower Extremities, 60	Femur	2
	Fibula	2
	Tibia	2
	Patella	2
	Tarsals	14
	Metatarsals	10
	Phalanges	28

53. Cartilage. — In infancy a considerable part of the skeleton consists of cartilage, or gristle, which afterward becomes ossified. But there are cartilages — such as the external ear, the rings around the windpipe, and the ends of various bones — which do not ossify, and are known as *permanent cartilages*. Cartilage is a smooth white shining tissue of close texture, rarely containing blood vessels. It is made up, like the bones, of cells surrounded by the intercellular substance which is the product of the living cells. A thin layer of cartilage covers the surfaces of the bones which come in contact with other bones. Cartilage also serves as padding in various parts of the body.

54. Connective Tissues of different varieties serve to complete the skeleton. They form the strong cords and bands and sheets called *ligaments*, for binding bones together, and the *tendons* which fasten the muscles to the bones.

55. Articulations. — All unions between bones are called *articulations*. Some of these allow of more or less movement; others permit no movement at all. The bones of the skull, with the exception of the lower jaw and the minute bones belonging to the inner ear, have no motion. In most cases their union is formed by means of toothed edges which fit into each other, forming irregular lines known as *serrated sutures*. They lessen jar and avert injury to the brain. The different vertebræ of the spine have a very slight motion upon one another, due to the elasticity of the cartilage pads or cushions which separate them.

56. Joints. — Where two bones are articulated in such a way as to permit one bone to glide freely over the

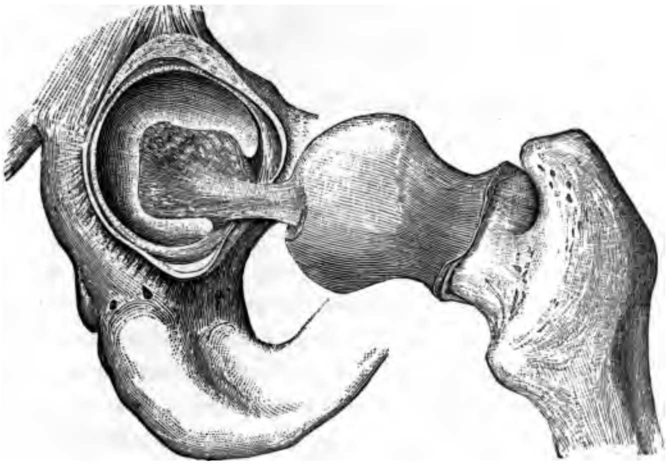


Fig. 34. — Ball and socket joint at hip.

The parts are separated to show attachments of the round ligament.

other, the union is called a joint. Joints are of various kinds and are adapted to various movements.

The *ball and socket joint* seen in the shoulder and the hip has the end of one bone fitted into the hollow of another, and provides for motion in any direction (Figs. 34 and 36).

Fig. 35. — Hinge joint of the elbow.
1 humerus. 2 ulna.

The *pivot joint* is that in which one bone rotates round another, as in the atlas and axis joint (Fig. 32), already described, and in the rotation of the ulna on the radius at their junction with the wrist.

The *hinge joint* permits of motion in one plane only, as in the joints of the fingers. Some hinge joints have provision for additional movements, as in the elbow (Fig. 35) and in the articulation between the lower jaw and the skull.

57. Synovial Membrane. — The broad, thin ligament surrounding a joint forms a closed sac. This sac is lined with the *synovial membrane*, which secretes a fluid whose purpose is to lubricate the joint, as oil lubricates the parts of a machine which move upon one another (Fig. 36).

58. Structure of Bone. — A living bone is tough, strong, and slightly elastic. Burned in a fire it retains its size and shape, but becomes brittle and easily crumbles to powder. Soaked for a few days in dilute muriatic acid, it also retains its shape, but becomes so flexible that, if one of the long bones, it may be tied in a knot. The fire destroys the 33 per cent of animal matter in the bone, leaving the calcium phosphate, calcium carbonate, and the small quantities of other salts which constitute the earthy or mineral portion of bone. The acid dissolves out the earthy salts and leaves the animal tissues.

On examination, one of the long bones in a fresh condition is seen to be covered at the two ends with smooth white *articular cartilage*, while the shaft is inclosed in a sheath of dense white fibrous membrane, called the *periosteum*, closely adhering to it. It is on the inner side of this membrane that the bone grows, and by it the nutri-

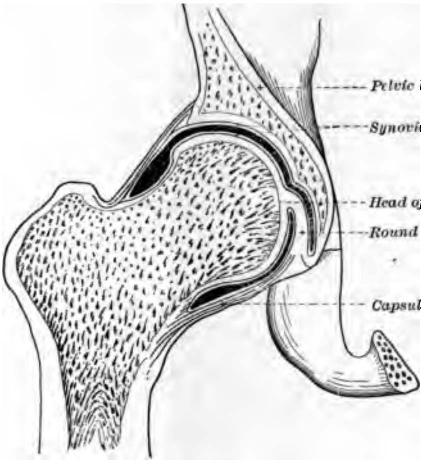


Fig. 36. — Section of hip joint.

tion of the bone throughout life is assisted. If the periosteum is torn away, the bone dies. It covers every part of the surface of a bone not covered by the articular cartilage, and into it the fibers of the ligaments extend, being so interwoven as to make an indistinguishable and inseparable junction.

59. Inner Composition of Bone. — If the bone is sawn through from end to end, the shaft is found to be hollow, with the *medullary cavity*, as it is called, in the center, filled with *yellow marrow*. The walls of the shaft are of a dense, solid structure, except for a thin stratum of

spongy bone around the cavity which contains the marrow (lower end of Fig. 37).

In the enlarged *articular extremities* of the bone, however, the reverse is the case. The firm, compact part forms only a thin layer on the surface, the rest being a loose, spongy network of bony matter, with the spaces filled with a soft, red substance called *red marrow*.

Fig 37.—Longitudinal section of the upper end of the tibia.

Interlacing channels, called the *Haversian canals*, run through the whole substance of a bone, in the densest as in the more porous parts. The periosteum is richly supplied with blood vessels, and from them minute branches enter the bone itself and run along the Haversian canals. Other blood vessels reach the solid portion of the bone from within, through the medullary canal of the center of the bone, and thus nutriment is conveyed to every part.

Each Haversian canal is surrounded by a set of hard bony plates, and between the plates, or *lamellæ*, are little

cavities called *lacunæ*, connected by minute canals with one another (Fig. 16, p. 25). Within the lacunæ and their canals are found little masses of protoplasm called *bone cells*, or *bone corpuscles*. These branching bone cells communicate with one another and with the blood vessels of the Haversian canals. They are the architects for building up the bony fabric. Each cell constructs walls which unite with those about them to form the solid mass.

Along with the arteries of the interior bony structure very fine nerve fibers have been traced, and lymph vessels are found in connection with the blood capillaries within the substance of all bones.

60. **Hygiene of Bones and Joints.** — The science of *hygiene* has to do with all that promotes normal action of the various parts of the body and of the whole mechanism. In respect to the bones we need to consider first the conditions most favorable to their growth.

61. **Bones of the Young.** — As the skeleton grows it not only becomes larger, but also becomes changed in the structure of its parts. The bones of an infant are almost wholly composed of cartilage, having the form of the completed bone, but the flexibility and elasticity of the cartilaginous tissue. They become slowly more firm and hard by a deposit of solid material furnished by the food, selected from the blood and lymph by the living cells in the cartilage and the periosteum. As the bone is built up by the deposit of the salts of lime (chiefly calcium phosphate), which furnish nearly all the earthy part of bone, the cartilage cells waste away, and their dead matter is carried off by the blood.

62. **Importance of Proper Food.** — It is evident that the food suitable for young children must contain lime and phosphorus in proper proportions for making bone. Milk

has been found to furnish, in most digestible form, those substances and others needed by the human infant, and is for early childhood the complete and perfect food. If there is not a sufficient supply of earthy matter in the food, the bones of a child remain soft and weak, and are easily bent or deformed, as in the disease called *rickets*. For such conditions an abundance of suitable food, with plenty of fresh air and sunshine, supplies the cure.

Alcohol and tobacco are particularly to be avoided during the time of growth, as they retard or prevent the full development of the bone cells, making the figure stunted and enfeebled. Cigarettes are especially harmful.

63. Deformity to be Guarded Against. — Children permitted to walk too early, before the bones are sufficiently hardened, may be made permanently bow-legged. They should be allowed freedom of movement and plenty of exercise, but should not be urged to walk too soon.

Long-continued pressure upon the bones of children may result in deformity. Some tribes of Indians flatten the heads of their children by fastening boards upon them. Clothing should always be loose; shoes especially should allow room for movement and growth.

Care should be taken that a child should habitually assume correct positions in sitting and standing, and frequent changes of position are needful. The seat should not be too high to permit the feet to rest easily and squarely upon the floor, otherwise the bones of the thigh may be bent by the weight of the legs. School children should be taught to sit upright while writing or studying, lest the spine become curved and diseased. Seats and desks should be carefully adapted to the child's stature, and round shoulders — the most common deformity — should be especially guarded against.

In standing, the weight should be supported evenly by the two feet. One hip or one shoulder often becomes higher than the other, upsetting the firm poise of the figure by neglect of this precaution. A teacher should see that a child is not kept standing till wearied.

64. Bones of the Aged. — As the bones of the young contain an excess of animal matter, so those of the old have an excess of mineral substances and are consequently more brittle. The aged, therefore, need to guard especially against fractures of the bones. Not only are their bones more easily broken, they are also healed with greater difficulty. In the young and healthy the vital processes are more actively carried on, and the busy bone cells go swiftly to work to repair a breakage, throwing out first around the injured parts a soft repairing material in which bony matter is afterward deposited; but in the aged the bone cells work slowly, and a broken bone is sometimes never fully restored.

65. Broken Bones. — The two ends of a broken bone should be brought together into their correct position as soon as possible, before inflammation and swelling render this difficult. Of course a skillful surgeon should be called to "set" a broken bone; but there may be delay, — the patient may have to be carried some distance. In such cases care should be taken to prevent injury to the surrounding parts from the fractured ends of the bone. A limb should be bound to a strip of board or even an umbrella as a temporary splint.

66. Injuries to Joints. — Dislocation of a joint stretches or breaks the ligaments and other membranes around it, producing inflammation. This renders examination and putting in place difficult, and a dislocated joint should therefore be restored to place as soon as the need-

ful skill can be procured. A sprain, which is a sudden wrenching or straining of the ligaments not sufficient to dislocate the joint, is often as serious as a dislocation. Neither should be neglected or treated lightly. Inflammation, if not checked, sometimes results in the destruction of the synovial fluid and the coverings of the ends of the bones in the joints, and consequently in permanent stiffness of the joint. Immediate and long-continued rest is imperative, and competent surgical advice should usually be secured.

Demonstrations and Experiments

10. *The Skeleton.* — For the study of the osseous system there should be accessible to the student a mounted human skeleton. In absence of this, a mounted skeleton of a cat or dog may be used. Where the school property does not include a skeleton of any kind, the enthusiastic teacher will provide one. This can be very quickly done as follows. Clean most of the flesh from the skeleton of a cat, dog, or rabbit; boil the partly cleaned skeleton in "liquid soap," one part, and water, four parts, for forty minutes, then for thirty minutes in liquid soap and water, equal parts; cool the skeleton in cold water; clean with a brush and allow to dry. The liquid soap is made by dissolving 12 grams of saltpeter and 75 grams of white soap in a mixture of 2000 cubic centimeters of water and 150 cubic centimeters of strong ammonia.

The skeleton may be studied without any attempt at mounting it. The student should follow the text of this chapter, identifying each bone as it is described. The teacher will find it profitable to have each student "demonstrate" the whole or a certain part of the skeleton, *i.e.* point out and name the various parts without any reference to the text and without leading questions from the teacher.

11. *Cartilage.* — At a meat market, bones can be procured which will show hyaline cartilage on their articular surfaces. At a slaughter-house can be obtained the windpipe, ears, costal cartilages, etc., of various animals, and the general appearance and purposes of the different varieties of cartilage can be shown from them. To show the

minute structure of cartilage, cut very thin sections with a razor from the articular surface of a fresh bone of a young animal, mount in normal salt solution, and examine with the compound microscope.

12. *Structure of Bone.* — Procure, at a meat market, a leg bone of some animal and compare it in appearance with a similar bone that has been exposed to the weather for months. Observe the pink color of the fresh bone, and the fibrous periosteum that covers it. Saw the two bones open lengthwise and observe the marrow cavity in each. Notice the compact shaft of each, and the cartilage on the articular surface of the fresh bone.

13. *Minute Structure of Bone.* — Mounted sections of bone may be procured of dealers in microscopical supplies, or the teacher may prepare them by sawing thin pieces from the shaft of a dry weathered bone and then filing them down till they are extremely thin. They may be mounted in water on a slide and examined with the microscope. But a better way is to dry the sections thoroughly, after carefully washing them in alcohol, and then to mount them in Canada balsam that has been evaporated until it solidifies on cooling. The sections should be quickly placed in the hot balsam upon a clean slide, covered with a cover glass, and cooled to harden the balsam.

14. *Composition of Bone.* — Two pieces of the same fresh bone or two similar fresh bones should be obtained. Burn one piece in a fire for several hours till it turns completely white. All the animal matter has been removed. Place the other piece of bone in weak muriatic acid (10–15 per cent strength) for several days to decalcify. It becomes soft, owing to the removal of the mineral matter. Observe the brittleness of the burned bone, and the toughness and flexibility of the other piece. Place the burned bone in the muriatic acid, and burn the piece of decalcified bone. What is left?

15. *Joints.* — The various kinds of joints can be demonstrated on a skeleton. The actual movements that occur at those joints should be performed by the student in corresponding joints of his own body.

16. *Dissection of a Joint.* — Procure a leg joint of a sheep and show the possible movements of the bones that form the joints. Observe the tendinous attachments of muscles, also the ligaments that hold the bones together. Cut through the ligaments and open the joint cavity. Notice the synovial fluid, and the cartilage on the articular surfaces of the bones.

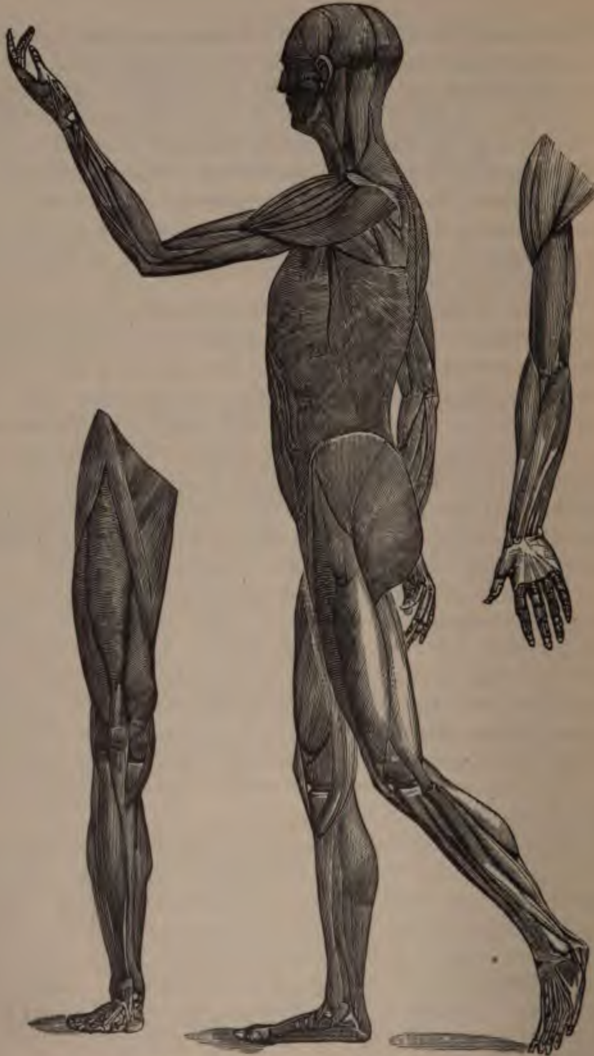


Fig. 38.—The muscular system.

CHAPTER V

THE MUSCULAR SYSTEM

Though the skeleton preserves the shape of the :he muscles with the surrounding fat fill out the giving roundness and grace of outline. Muscles ›nes, with the tendons and ligaments connecting constitute the organs of motion and locomotion: re the apparatus by means of which the nervous acts when the object sought is movement; as the :h, liver, blood vessels, kidneys, and other parts digestive system are the apparatus which the nerv- 'stem uses for the ;e of nutrition.

The Muscles are the art of meat. They ıp that part of the vhich we call flesh. a muscle is exam- t is found to consist ıll fibers bound to- in bundles (Fig. ›ach bundle being ed in a thin sheath olar tissue, called *perimysium*, while each minute ›f which a bundle is composed has also its mem- ıs sheath, called the *sarcolemma*.

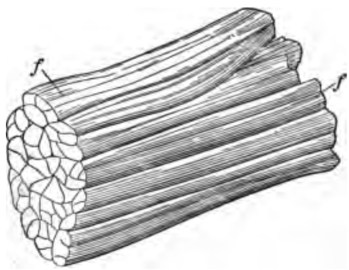


Fig. 39.—Bundles of striated muscle cut across.
ff several bundles bound together into larger bundles to make up the muscle.

69. Classification.—The muscles are divided into two classes, usually called the *voluntary* and the *involuntary* muscles, the first being under the control of the will, while the second are not. There is also a difference under the microscope between the two classes of muscles. Voluntary muscular tissue is composed of fibers which are marked by alternate dark and light stripes. They are called *striated* or *striped* muscular fibers (Fig. 40). The fibers which compose the involuntary muscles are, as a rule, destitute of these markings and are called *plain* muscular fibers (Fig. 41).

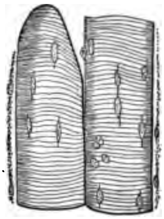


Fig. 40.—Pieces of striated muscle fibers.

Showing the spindle-shaped nuclei and cross-striations. At the left above is the rounded end of a fiber.

Certain exceptions to the above rule should be noted. The muscles of the heart, though not under the control of the will, are made up of striped muscular fibers; and also the muscular fibers found in the pharynx, part of the esophagus, and in the internal ear, though involuntary, have the structure of voluntary muscle fiber. On the other hand, the *ciliary* muscles, by which the eye is accommodated for seeing objects at different distances, are under the control of the will, though composed wholly of plain or unstriped muscle fibers.

Fig. 41.—Plain muscle fiber.
N nucleus.

Some striped muscles, like those of respiration and of the eyelids, are partly voluntary and partly involuntary.

70. Voluntary Muscles.—These are also called *skeletal* muscles, because they constitute the muscular apparatus attached to the bones. Each muscle is usually larger in

the middle than at the ends, and the swollen middle portion is called the *belly*. The belly is usually unattached, but the two ends are secured to the bones by tendons which are continuous with the connective tissue of the muscle (Fig. 42).

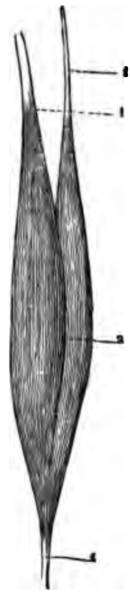


Fig. 42. — Biceps muscle.

1 tendinous ends.
2 belly.

Between the small fibers of the bundles which make up a muscle is a little loose areolar tissue in which are distributed the blood vessels and nerves for the muscle.

71. Muscle Cells or Muscle Fibers. — It is in the microscopic threads of the muscle that the peculiar power of contraction lies. These are variable in length and thickness, but are said to average, in voluntary muscles, $\frac{1}{500}$ of an inch in diameter and about one inch in length. They are cylindrical in shape, with rounded ends (Fig. 40), and as a rule do not branch. In the muscles of the face and tongue, however, the muscle fibers divide into many branches.

Each *muscle fiber*, or *cell*, consists of the *sarcolemma* and a soft, semifluid material of alternate light and dark disks, called the *contractile substance*. Just beneath the sarcolemma are several long oval nuclei.

72. Nerve Endings in Muscle Fiber. — It is impossible to treat of muscles and their action without including some study of the other sort of irritable tissue, *nervous tissue*, upon which muscular action depends.

The sarcolemma of each muscle fiber is pierced by a branch of a nerve fiber. The *primitive sheath* or *neuri-*

lemma (the inclosing membrane of the nerve fiber) becomes continuous with the sarcolemma, and the axis cylinder of the nerve fiber branches many times, the ramifications ending in a flat or branched layer of protoplasm containing nuclei. These terminal nerve organs are called *end plates* (Figs. 43 and 44).

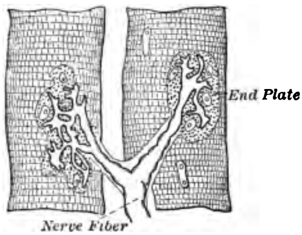


Fig. 43. — Nerve endings in striated muscle fibers.

73. How a Muscle Contracts. — A muscle contracts or becomes shorter in proportion to its length, without change in bulk, under the influence of *stimulus*. It is the office of the nerves of the muscles to carry to them their natural stimulus, but muscles also contract under the action of other stimuli; for instance, in consequence of a sudden blow or pinch, when heat is applied suddenly, when certain chemical substances are dropped upon them, or when an electric shock is conducted to them.

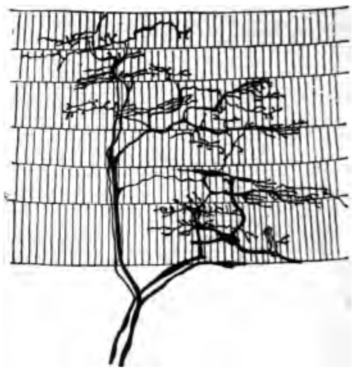


Fig. 44. — Motor nerve endings in striated muscle fibers.

In living animals the muscles are always more or less contracted. This is due to the nervous influence which they constantly receive. If their nerves are cut or destroyed, the muscles lengthen. This tension of the muscles keeps them ready for immediate action. When a nervous impulse

reaches a muscle, the numerous branches of the nerve — one for each individual muscle cell — distribute the stimulus to all parts at practically the same instant. The end plates are situated in each muscle fiber near the middle between the two ends, and the fiber begins there to contract. The two ends draw toward each other; the fiber becomes swollen and shorter. In the muscle as a whole contraction is simply the sum of the contractions of all the minute fibers which compose it. In the muscle fiber contraction appears to be some complicated movement of the molecules which produces a change in the appearance of the stripes. It is found that in those places where swift and rapid contraction is called for, the muscular tissue has almost invariably the striped fibers.

74. When a muscle is made to contract by a single electric shock, or by other artificial means, the movement is sudden and brief. Voluntary muscle, however, under its natural nervous stimulus, never contracts with a twitch. Its action is rather that of continued gentle vibration, called *tetanus*, such as follows a rapid series of electric shocks which leave no time for relaxation. The nervous stimulus comes to the muscle in a quick succession of impulses, — about twenty in a second, — so that one vibration is succeeded by a second before the first has ceased to agitate the muscle cell.

75. Internal Changes in Muscle under Stimulus. — Some of the energy set free by a contracting muscle appears as work done, weight lifted, etc., while a considerable amount becomes heat, for the temperature of muscle always rises under contraction. Certain chemical changes also appear. Variable amounts of carbonic acid and lactic acid are set free, and oxygen is used up. Electric changes

lasting for some time are also produced in the muscle by its contraction. These are shown by the use of a delicate galvanometer.

76. Another important effect upon itself of a muscle's contraction is what we call *fatigue of the muscles*, that is, a lack of readiness to respond to stimulus. This is due to the using up of the material in the muscles which was available for the production of energy, and still more to the accumulation of waste matter — the product of the activity of the muscles. Experiments have shown that it is not the muscle itself which first becomes too much fatigued for contraction. Nor is the seat of fatigue in the nerve, but *in the end plate within the muscle cell.* The fatigue is relieved by even a brief rest, and such relief is absolutely necessary to the health of the muscles. Even the muscles of the heart, that organ which works ceaselessly from the beginning of life to death, have a period of rest after each beat.

77. External Effects of Muscular Contraction and Relaxation. — The purpose of muscular contraction is the production of motion. The contraction and relaxation of the muscular walls of the heart keep the blood in constant movement; the various other vital processes are also dependent upon more or less constant motion in the tissues and organs of the body, and all our outward activities are likewise the results of the shortening and lengthening of the innumerable strands of muscular tissue.

Muscular power, or the amount of force which a muscle can supply, varies with its health and vigor, and with its form. The thickest muscles can lift the heaviest load. Those having the longest strands can move a weight the greatest distance. Hence the human body possesses both long, slender muscles, and short, stout ones,

as well as those of all sizes and lengths between. Many muscles which we might at first think to be long are really short, but appear long because of the long tendons by which they are attached to the bones. Many of the muscles which move the fingers, for example, have their bellies in the forearm, and are attached to the small bones of the fingers by long, slender tendons. The force with which muscles contract is sometimes very great. A human muscle one square centimeter (.15 square inch) in section can raise a weight of 5670 grams or 200 ounces.

When a muscle contracts, its two ends are drawn nearer together, and hence draw toward each other the parts to which the ends of the muscle or its tendons are attached; the belly of the muscle becomes swollen, and in strong contraction the whole muscle becomes tense and hard.

78. Contraction is speedily followed by relaxation. The stimulating force ceases to be supplied, and the muscle returns to a state of rest. If the hand has been raised by the contraction of the *biceps* muscle on the inner side of the humerus, it will fall under the action of gravitation when that contraction ceases and the muscle becomes passive. In order that the hand may be drawn down with force the action of the *triceps* muscle at the back of the humerus is needed. Muscles can give a powerful *pull*, but they cannot *push*. Very generally, therefore, they are arranged so that muscles which cause movement in one direction are opposed by those which cause movement in the opposite direction.

79. Dead Muscle. — The muscles of a dead body, or muscles which have been removed from a living body, gradually undergo a marked change, which results in the stiffening known as *rigor mortis*. That which was translucent becomes more opaque, most of the natural

elasticity disappears, and a hard, rigid condition sets in, accompanied by more or less contraction. This is due to a coagulation of the protoplasm of the muscle cells, similar to the clotting of blood. *Rigor mortis* passes away after a time, and the dead body becomes soft and flabby — a sign of approaching decay.

80. Plain or Involuntary Muscles. —Though the plain muscles are not under the control of the will, they still have nervous connection with the central nervous system. Most of the nerves supplying the organs having *plain* or *unstriped* muscular tissue come from the ***sympathetic nervous system;*** but from every ganglion of the sympathetic chain nerve fibers communicate with the brain and spinal cord. The muscles of the blood vessels, lymphatics, glands, and other internal organs, are of unstriped structure, and carry on their work without affecting consciousness. Their action under stimulus is similar to that of the skeletal muscles, but takes place much more slowly.

81. Plain Muscle Fibers. — Plain muscles are made up, like skeletal muscles, of bundles of fibers, and these of muscle cells. The cells, however, differ from those of the voluntary muscles. They are long, spindle-shaped fibers, having a rod-shaped nucleus in the center (Fig. 41). The nerves of plain muscle fibers do not end in end plates, but form *plexuses*, or networks, which ramify between and around the muscle fibers. The nerves of the heart muscles end as do those of the unstriped muscles.

82. Rhythmic and Peristaltic Movements of Involuntary Muscle. — One of the characteristics of involuntary muscles is a tendency to alternate regular periods of activity and rest. The heart is the most familiar illustration of this rhythmical tendency, but it is seen in some other organs, and especially in some of the lower animals.

The *peristaltic* action of plain muscle is seen in the small intestine and in other parts of the alimentary canal. When any part of the tube is stimulated, a circular contraction results, which slowly passes along in a wavelike manner through the length of the tube. In the digestive tract this movement serves to drive the food onward.

83. Involuntary muscle, as a rule, contracts more slowly than voluntary muscle. It contracts, not with a tetanus like that of voluntary muscle, but with a single, much prolonged contraction.

84. Mechanism of Movement. — The power of the muscles to change their form carries with it the power to change the positions of the bones and other parts of the body to which they are attached, and hence to change the positions of the different parts in respect to one another and to move the whole frame from place to place.

When a part of the body is moved at a joint, the bone which is moved acts as a lever. A lever is a stiff bar which can be moved round a fixed point, or fulcrum. Three classes of levers are known to the science of mechanics, depending upon the position of the fulcrum with reference to the weight to be moved and the power which produces the motion. In the first class the fulcrum is between the weight and the power, as in using a crowbar to lift the edge of a stone. In the second class the fulcrum is at one end, the power at the other, and the weight between them. In the third class the fulcrum is at one end, the weight at the other, and the power is applied between the two. All three forms of levers are found in the human body, though the levers of the third class are the most numerous (Fig. 45).

85. Lever of the First Class. — The action of a lever of the first class is seen in the straightening of the bent arm.

The muscle at the back of the humerus applies the power. It is attached by tendons to the scapula and to the hinder side of the humerus, while the tendon into which the lower end of the muscle narrows is inserted into the end of the ulna at the elbow, which is more than an inch above the articulation of the ulna with the humerus. By its contraction the muscle pulls the upper end of the ulna upward, drawing down the hand, which is the weight at the lower end of the ulna, and straightening the joint. The fulcrum is at the elbow joint, between the hand and the power at the upper end of the ulna.

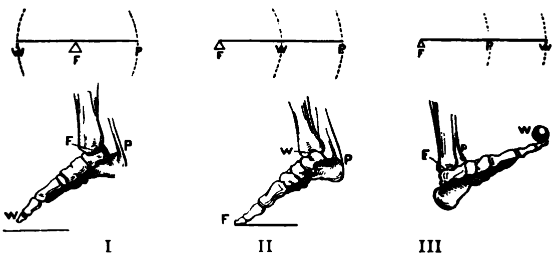


Fig. 45. — **Diagram of the foot, illustrating levers of the three classes.**
I tapping the toe on the floor. II rising on the toes.
III lifting a weight with the toes.

86. Lever of the Second Class. — When the body is raised on the toes (Fig. 45, II) the action of a lever of the second class is seen. The weight is that of the whole body supported by the foot at the ankle, while the power operates through the muscles of the calf of the leg at the heel, the toes acting as the fulcrum.

87. Lever of the Third Class. — When the body lying on the ground is raised to a sitting posture, a lever of the third class is used. The head and body are the weight, the fulcrum is at the hip joints, and the power is applied

between the two by the muscles which pass from the front of the thigh to the hip bones. The raising of the hand by bending the elbow joint is perhaps a clearer example of the lever of the third class. The weight is at the end of the forearm, the fulcrum is at the elbow, and the power is between, at the point on the radius where is inserted the muscle which lies on the front of the humerus.

88. Coördination of Muscular Action.— Our ordinary movements involve the use of many different muscles, and very complicated action of levers and cords. Even simply to stand erect requires strong tension of certain muscles and ligaments pulling against one another. The muscles on the front of the thigh contract to keep the knee from bending, while the ligaments of the joint prevent it from bending the wrong way. The muscles on the front of the leg contract to keep the body from falling backward, and those at the back contract to keep it from falling forward. In the same way the trunk is balanced on the thigh bones by the muscles passing from the body to the thigh in front and back, while a particularly strong ligament, crossing the hip joint from the pelvis to the thigh bone, keeps the extra backward weight of the trunk from destroying the balance of the frame. At the back of the neck are the muscles which give to the head its erect and graceful poise, while many ligaments bind it to the spinal column (Fig. 46).

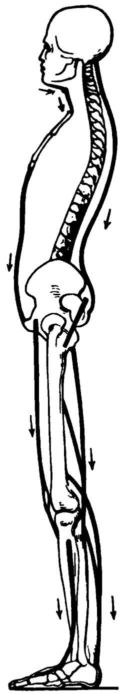


Fig. 46.—Diagram of some of the muscles which tend to keep the body erect.

89. In order to maintain all the nice adjustment and balance of muscular force constantly demanded, the brain and nerves must be continually at work. Just enough stimulus must be supplied to each set of muscles and supplied at exactly the right moment or something will at once go wrong. This harmony of muscular action and regulation of the complex relations between the hundreds of muscles in the body is called *coördination.* It is easy to show that it depends upon the nervous system.

If one falls asleep or receives a blow which "stuns" the brain, the muscles are relaxed, and, unless supported, the body falls to the ground. Sudden nervous or emotional excitement, as surprise, grief, or fear, may cause the muscles of the heart to stop their action and the body to fall in a "faint." In some cases the effect of sight upon the brain is to destroy the power to control the muscles, as when the sight of the moving waves of lake or ocean renders one giddy. The perception of certain odors may have the same effect, and in many other ways the control of the muscles is affected by that which affects the central nervous system.

The study of the brain has shown that the *cerebellum* is the great center for the coördination of muscular movement and especially of those muscular actions which have to do with maintaining the equilibrium of the body.

90. Exhaustion of Muscles. — Even when we are quite awake, and the brain is active, our muscles sometimes refuse to act. Muscular fiber cannot contract continuously for a long time. It must have periods of rest. That is the reason we require frequent changes of position, one set of muscles being thus allowed to rest while another set is called into action. If a weight be held out at arm's

length from the shoulder, the muscles of the arm soon become exhausted and incapable of sustaining the weight. But a moment's rest restores the contractile power, and the weight may again be held out.

91. Muscle Waste. — When a muscle contracts certain chemical changes take place in the substance of its cells. Some of the matter in the muscular fiber becomes oxidized, and new substances are formed which are harmful to the body if not removed. These are called *waste products*, and that which appears in largest quantity is carbon dioxide. These waste products are taken up by the blood which flows along the muscle cells and are finally removed from the body by means, mainly, of the lungs and the kidneys. If the waste matter is not removed, the effect soon appears in the central nervous system, to which the poison is carried by the blood.

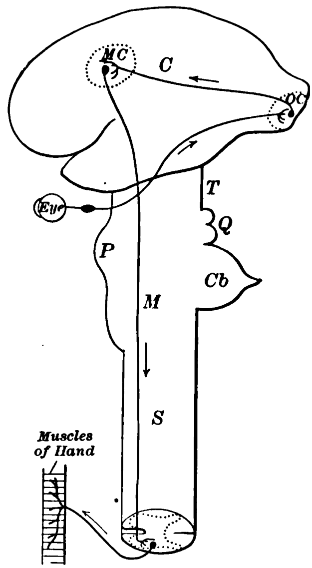


Fig. 47. — Diagram of the path of a nervous impulse which results in the hand reaching to seize an object seen with the eye.

C cerebrum.
Cb cerebellum.
M medulla oblongata.
MC motor center in brain.
OC optic center in brain.
P pons Varolii.
Q corpora quadrigemina.
S spinal cord.
T optic thalami.

92. Voluntary Movement. — Let us suppose that a man seeing an apple within reach puts forth his hand to take it (Fig. 47). In such a case the light from the apple enters the organ of sight and stimulates the nerve endings

appropriated to vision. The nervous irritation is conducted by the optic nerve to that part of the brain concerned in perception by means of the eye. The nervous center is affected, and the nervous impulse is passed on, by some unknown process which we speak of as the action of the will, to the nerve fibers running down the white columns of the spinal cord. These convey the impression to the *anterior horn* of the gray matter of the cord, where lie the *motor cells* from which arise the *motor roots* of the spinal nerves. From the motor cells a new nervous impulse goes forth to certain muscles of the arm and hand. The muscular cells of such muscles contract, the bones are moved at the joints, and the apple is seized. This is voluntary muscular action.

93. Reflex Movement. — The voluntary muscles often act without receiving any nervous impulse from the brain,

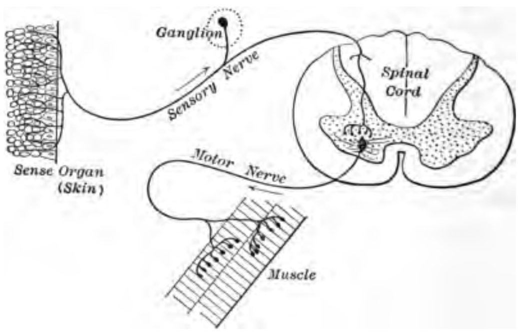


Fig. 48. — Diagram of the path of a simple nervous reflex action.

and without any conscious purpose. Suppose the man in putting out his hand to take the apple is stung upon the finger by a wasp not before perceived. The end organ of sensation in the finger sends the impression of pain

along the *afferent sensory nerve* through the posterior nerve root to the cells of the spinal cord, and an impulse is at once sent forth along *efferent motor fibers* to the muscles of the hand and arm, which promptly jerk the hand away (Fig. 48).

A great multitude of reflex actions are possible to the muscles, and one of the chief functions of the spinal cord is to act as a center of reflex action.

94. Automatic Movement. — Action of the muscles often occurs without any obvious stimulation of the nerves from without. That is, the nervous impulse may apparently arise in the nerve center itself, and *efferent*, or outgoing influences are not preceded by *afferent*, or incoming influences. Such changes often occur *rhythmically* — activity and rest, or diminished activity, following each other in regular alternation — as in the movement of the muscles of respiration; and this characteristic is believed to be due to certain rhythmic changes which take place in some of the nervous material of the medulla oblongata.

95. The Muscular Sense. — It is not motor nerve fibers only that are distributed to the muscles; the muscles receive sensory fibers also which pass to the posterior roots of the spinal nerves and convey impressions from the muscles to the spinal cord and thence to the brain. These impressions are called *the muscular sense.* They assist our judgments of weight, and inform the brain of the general condition of the muscles.

96. Hygiene of the Muscles. — Muscles increase in size and in strength by appropriating suitable material from the food, and by use. If ill fed and inactive, they become small and weak. If one limb is made useless from disease or injury, — as when a bone is broken, — its muscles shrink and grow soft, so that the unused limb

becomes perceptibly smaller, and, of course, weaker than its fellow.

97. Exercise is indispensable to health of muscles. Growing children need much active exercise for developing and hardening the muscles, and all healthy children crave it. Nothing is better than running and walking for promoting the growth of the muscles, for developing the power of the lungs and the heart, and so for aiding both the free circulation of the blood and its purification, by means of which the nutrition of the whole body is stimulated. Those who exercise much in the open air (which is always best) have, as a rule, good appetites, for food is needed to repair the waste caused by the exercise.

Many diseases are prevented, and some are cured, by suitable exercise. A brisk walk of several miles taken regularly every day would alone do much to keep the whole body in normal condition. If it is impossible to go out of doors for the needful amount of exercise, the indoor conditions should be as nearly as possible like those without. Fresh air and light should be freely admitted to the rooms used, additional clothing being put on when necessary.

Rowing, swimming, boxing, horseback riding, climbing, sweeping, cycling, etc. are of value in strengthening the muscles of the limbs, chest, and back. A large, strong chest, wherein the lungs have plenty of room for an abundance of pure air, is not likely to belong to a consumptive person.

It is desirable that exercise should be chosen which develops both sides of the body. Throwing a ball with one hand, if indulged in to excess or without sufficient exercise of other sorts, sometimes causes irregular development of the body, and curvature of the spine may fol-

low. Certain kinds of spinal curvature are cured by wisely chosen exercise.

98. Exercise in the Cold. — For a healthy person nothing so well develops the whole system and hardens the constitution as regular, vigorous, and agreeable exercise *in the cold*. Hence outdoor winter sports and occupations should be encouraged. Skating, sliding, snowballing, and swimming are excellent as promoters of health.

99. Time for Exercise. — Some times are better than others for taking exercise. The morning is usually best for the severer forms, because the whole system is then refreshed and vigorous. In the evening one who has been engaged in physical toil does not need exercise, but rest; while one whose occupation is mental labor or sedentary business will be rested and refreshed and prepared for sound sleep by exercising judiciously in the open air after the day's work is done.

When the muscles are called into use they require more blood than when at rest, that the waste which results from exercise may be repaired. This extra supply of blood is drawn from other parts of the body, and the demands of the muscles may retard the performance of other physiological functions — since the total amount of blood is practically invariable. This is why the muscles should not be vigorously exercised for an hour or two, at least, after meals, and not immediately before. Digestion requires an increased flow of blood to the alimentary canal and digestive glands, and if the process is impeded by a drain of the vital fluid to other parts, harm will result.

100. Training. — The scientific development of the muscular system under "training" for particular purposes of sport, or in a well-equipped gymnasium, may have excellent results for those who are able to avail themselves of

such facilities. But the number of such persons is comparatively small, and as those who exercise in a gymnasium are usually, and ought always to be, under the guidance of a qualified instructor, advice as to the use of the gymnasium apparatus is not needed here.

101. The Healthfulness of Work. — While all due stress should be laid upon the healthfulness of recreative exercise, it should not be forgotten that the human machine is the most skillfully designed and constructed apparatus ever made for accomplishing an immense variety of different kinds of *work*. The man whose daily employment brings into play his various muscles under conditions of reasonable comfort, and without overfatigue, may live a healthful life without paying any attention to the preceding suggestions. If that employment is carried on in the open air, and is such that he finds interest and enjoyment in it, he is still more fortunate. All the good effects of the most carefully devised systems of physical culture may be gained from a judiciously varied scheme of work, and the pleasure of being able by one's own effort to create some useful or beautiful or worthy product for the enrichment of the world may be a tonic even more healthfully stimulating than the most successful athletic contest. The varied round of household duties, sometimes prescribed by a wise and skillful physician, has in many cases brought health to a feeble, languid, ailing woman. The effort which the idle rich man sometimes puts forth in the way of exercise, that he may secure an appetite for his dinner, would be still more promotive of health if turned to some useful purpose.

The man whose business does not permit the proper activity of all the muscles must necessarily give thought and time to supply the deficiency. But to the great mass

of mankind it is happily possible to get all needful exercise while doing useful work.

102. The Nervous System as involved in Muscular Exercise. — We have already learned that contraction of voluntary muscular tissue depends upon the stimulus brought to each minute muscle cell by a nerve fiber. Without such stimulus a man's limbs are motionless and the whole frame a lifeless mass. If the nervous system is enfeebled by disease or by exhaustion, the action of the muscles becomes weakened or deranged. The disease called *Saint Vitus's dance*, which causes muscular movements beyond the control of the will, is not a disease of the muscles, but of the nerves. So in other disorders which derange the action of the muscles, the real trouble is seldom with the muscular tissue itself. The direct effect of muscular activity, as suggested in section 91, is to poison the nervous centers. The greater the demand upon the muscle in the way of rapid and frequent contraction, the greater the consumption of living material and the greater the amount of poisonous, dead, waste matter which passes into the circulation. These waste products, if not promptly removed from the system through the excretory organs, are found to have a powerful injurious effect upon the central nervous system, an effect that is soon manifest in the weakened action of the muscles themselves.

Anything, therefore, which affects injuriously the nervous system interferes with the free and easy play of the muscles. And, conversely, anything which promotes a high level of health in the nervous system is an aid to muscular vigor also. Exercise undertaken for the carrying out of some worthy purpose — a purpose in which the mind is deeply interested and the whole man engaged — is the most healthful exercise; while that which is disliked

or entered upon indifferently and listlessly is found to have little or no invigorating power.

103. Effect of Alcohol and Other Stimulants and Narcotics upon Muscular Action. — The most serious effects of the excessive use of alcoholic drinks, tobacco, opium, chloral, and other narcotic drugs are felt by the nervous system and will be most fully treated when we come to the special study of that part of the human organism. But it is well to notice here how those substances influence the organs of motion.

No one who has ever seen a drunken man in the stage preceding that of stupor can have failed to observe the uncertainty of his muscular movements: the shaking hand, the staggering gait, the thick, indistinct utterance. These effects are due to what is called the *excessive* use of alcoholic drinks, and no one doubts that in large quantities they act injuriously upon the system. Alcohol deranges the action of the muscles by its influence upon the nervous system, causing defective regulation of the supply of nervous force to the several muscles. As to whether it is possible to use alcohol in small amounts without impairing the perfection and vigor of muscular action, there is one very significant fact: that men in training for severe muscular exertion in athletic contests are strictly forbidden the use of alcohol in any form and in any quantity, whether or not they have been previously accustomed to such indulgence. As the rules for such training are the result of long and wide experience and most careful study, it is safe to conclude that alcohol at least does not promote strength, endurance, or precision of muscular movement.

It is very common for a person accustomed to a moderate use of alcoholic beverages to suffer from tremor of the hands, due to lack of control over the muscles, so that

he is disabled from manual work requiring dexterity or skill. Sometimes an additional glass of liquor seems to steady the hand for a time, but the shakiness soon returns.

104. Tobacco and other narcotics also affect muscular activity through their effect upon the nerves. All narcotics have as their natural, characteristic influence the paralyzing of some of the nerve centers. As medicines they may give relief from pain and so act beneficently under skillful application. Tobacco has a special effect upon the nerve centers regulating the action of the muscles of the heart, making that action irregular and less vigorous. This is particularly true of the young, and it is not very uncommon for boys addicted to excessive cigarette smoking to develop serious disease of the heart, or even to die suddenly from "heart failure." Smoking tobacco is found to interfere with work requiring fine and delicate adjustment of muscular movement, as in watch making and other delicate mechanical employments, in scientific drawing, fine penmanship, etc. It is also forbidden to those persons in training for athletic contests, and to all pupils in many schools, as well as to soldiers in the armies of certain countries.

Demonstrations and Experiments

17. *General Structure and Properties of Muscles.*—It is important that the pupils see muscles in their natural positions and connections. For this purpose the frog is convenient, since the animal is so small that little dissection is necessary, and since entire muscles can be observed and owing to their great vitality can be made to perform their natural movements. The frog should be pithed or decapitated, and the skin removed from one of the hind legs. The muscles of the limb then stand out distinctly (Fig. 7, p. 18). The belly of a muscle can be distinguished from its tendinous ends, and the origin

and the insertion can be made out. The respective share which each muscle takes in the movements of the limb can be shown by touching the individual muscles with the electrodes of a weak galvanic battery. The change in shape of the muscle during contraction will also be very well shown.

18. *Relaxation and Contraction of Muscles.* — Extend one arm nearly straight from the shoulder. Then bend the arm at the elbow, drawing the hand up to the shoulder. With the other hand can be felt the changes in the form of the biceps muscle, as it relaxes and contracts. If the arm be bared the changes in form of the muscle can be seen. The tendon of the biceps at the elbow can also be seen.

19. *Gross Structure of Muscle.* — Obtain a piece of boiled corned beef, and dissect it with needles. The larger and smaller bundles of muscle fibers can be easily differentiated. By aid of a lens even the separate fibers can be isolated. Observe between the bundles and fibers the whitish connective tissue, in life tough and fastening the bundles and fibers together, but now softened in boiling.

20. *Functional Difference between Voluntary and Involuntary Muscle.* — If the abdominal cavity of the frog experimented upon in a preceding section be opened and the electrodes applied to the stomach and intestines, the difference between the movements of voluntary and involuntary muscle will be clearly demonstrated.

21. *Fatigue of Muscle.* — On applying repeated electric shocks directly to a frog's muscle, or indirectly through its nerve, the responses are seen to become more and more feeble. But after a period of rest, the muscle responds as vigorously as ever.

22. *Nerve Endings in Muscle.* — While the tracing out of the final nerve ends in muscle must be left to the histological expert, yet the general relations of motor nerves to muscles can be very easily shown in the frog. Branches of the sciatic nerve can be traced out to the muscles of the leg (Fig. 8, p. 18), and by electrical stimulation the functional relation between nerve and muscle can be shown.

23. *Rigor Mortis.* — Observe in a frog, just after decapitation, that the muscles are soft and relaxed. Shortly after the tissues have completely lost their vitality, the muscles will be found to be hard and contracted. The limbs which may have been bent at the joints and limp, are now straight and rigid. Death rigor or *rigor mortis* has set in. After some time, the muscles again become flaccid and putrefaction soon begins. Place fresh muscle in hot water, and observe that

heat rigor is at once manifest. In both cases, the rigor is due to coagulation of the muscle substance.

24. *Minute Structure of Voluntary or Striped Muscle.* — With needles tease out, in normal salt solution, on a glass, a small piece of skeletal muscle of a frog or other animal. Mount and examine with the compound microscope. It will be seen to be composed of elongate thread-like bodies, tapering (when not broken) at the ends. Some fibers will show cross markings.

25. *The Minute Structure of Involuntary or Plain Muscle.* — Tease out, as in the foregoing, a small piece of the outer wall of the intestine of a frog or cat. Here the fibers are seen to be spindle-shaped cells, much shorter than the striped muscle fibers.

The fibers of both striped and plain muscle can be much more easily teased apart if the tissue be kept in a 20 per cent solution of nitric acid one to two days.

26. *Cross Section of Muscle. Minute Structure.* — If a prepared cross section of a small skeletal muscle can be obtained, the internal structure of a muscle can be very well shown by aid of the compound microscope.

27. *Minute Structure of Tendon and Ligament.* — Carefully tease out in normal salt solution, on a slide, a small piece of a thin tendon from the tail of a mouse. To obtain the tendon, cut off the tail from the body, and then pull out the delicate tendinous threads from the cut end. The tendon should be mounted immediately after removal, to avoid drying. A convenient method of mounting is to stretch the tendon across a slide, through a drop of normal salt solution in the center, allowing the ends of the tendon to adhere to the dry edges of the slide. On examining with the compound microscope the tendon is seen to be composed of wavy bundles of fibers. If the preparation be treated with a one per cent solution of acetic acid, the fibers will swell and disappear from view, but there will appear, between the bundles, rows of spindle-shaped cells.

CHAPTER VI

THE SKIN AS AN ORGAN OF SENSATION — TOUCH

105. Functions of the Skin. — The whole body is covered with a flexible, elastic membrane of complex structure, which serves several different purposes. It envelops and protects the inner, soft parts, and especially the ends of the nerves. It is one of the three principal channels by which the waste products of the body are removed — that is, it is an organ of *excretion*. It regulates the temperature of the body by controlling the loss of heat through general radiation and evaporation, as well as by the direct action of the sweat glands in excretion. A small amount of respiration, or exchange of gases, also goes on in the skin, and it contributes by its general characteristics and its various modifications to the ornamentation of the body.

106. Structure of the Skin. — The present chapter has to do with the skin as one of the organs by means of which the nervous system is brought into direct communication with the external world, that is, as the seat of the sense of touch and of certain other allied nervous impressions.

Two distinct layers are found in the skin, called the *epidermis*, or *cuticle*, and the *dermis*, *corium*, or *true skin* (Fig. 49). The *epidermis* is composed of epithelial tissue, or epithelium, and its cells lie in layers one above another, the outer or *horny layer* of cells being flat,

dry, and unnucleated, or dead. The epidermis contains no blood vessels, but in the deepest layers are found minute terminations of some of the nerve fibers; and in the same layers are the fine granules called *pigment* which give color to the skin. This coloring matter is powerfully affected by sun and wind, causing tan and freckles.

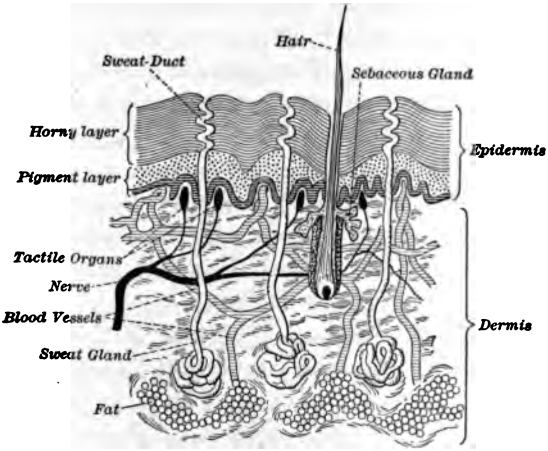


Fig. 49.—Diagram of section of the skin.

107. Hair and Nails are peculiarly developed forms of the cuticle. Each hair is a long filament growing obliquely from a little bulb called a *papilla*, lying in a hollow called the *hair follicle*, which reaches down below the skin into the areolar tissue beneath (Fig. 49). The part of a hair buried in the skin is called its *root;* the remainder, the *stem*, which tapers to a point. The stem is covered with scales overlapping like the scales of a fish and projecting toward the point. When a hair is pulled out by the root, a new one will grow again so long as the papilla is uninjured. Each hair contains pigment granules which

give its color. There are also cavities filled with air. These small bodies of inclosed air are very abundant in white hair, and, reflecting the light, are the cause of its color, just as the whiteness of snow is due to the many reflections of light from the tiny bits of ice which compose it.

In the *nails* the horny layer of the epidermis is greatly developed. Each nail has its root firmly embedded in a groove of the cuticle. The under side is fixed to the dermis except at the end of the finger or toe, where there is a *free edge*.

The hair preserves the temperature of the head and is also a protection against injury. The nails protect the sensitive ends of fingers and toes and aid in their mechanical operations. Both hair and nails also help in the ornamentation of the body.

108. Mucous Membrane. — Not only is the whole outer surface of the body covered with the skin, but all the inner cavities and passages which have an external communication are also lined with it. These inner linings are, however, of a modified form of skin called *mucous membrane*, because it secretes a viscous fluid, or *mucus*. This membrane is thinner, redder, and more sensitive and delicate than the outer skin, but is of the same general composition; that is, it has the two layers, the outer bloodless and insensible, the inner highly sensitive, soft, fully supplied with blood vessels, glands, etc.

109. The Dermis, or True Skin, is a close network of connective tissue fibers, forming a dense, tough, firm envelope for the body, resting upon and gradually passing into the areolar tissue beneath, which is a loose network of interlacing bands and cords with meshes between. Ramifying through the dermis are nerves,

blood vessels, and lymphatic vessels, and it contains great numbers of sweat glands and oil glands.

The epidermis, lacking blood vessels, does not bleed, and the horny layer, lacking nerves, has no feeling; but so fine are the networks of blood vessels and nerves in the dermis that the finest needle cannot pass between them. The whole surface of the dermis is thrown into innumerable projections called *papillæ*, many of them supplied with capillary blood vessels and nerve fibers.

110. Sensation. — When we become conscious of receiving an impression, — that is, when we perceive that some part of our nervous system is stimulated, — we have what is called *sensation*. It has already been shown that nervous stimulation may affect parts of the nervous system and reflex action may follow without conscious reception by the brain of any influence — that is, without sensation.

In order that there may be sensation there must be (1) a *stimulus*, (2) a *nervous end organ* suited to receive the stimulus, (3) a *path to the brain* for the impulse excited by the stimulus, (4) a *part of the brain to receive the impulse*. Still another condition of a different sort seems essential to sensation, and that is an attitude of the mind which we call *attention*. A person absorbed in thought may look upon an object without being conscious of perceiving it, may hear music without knowing it. That is, all the conditions of sight and hearing may be present save the one of attention, for which we have as yet no physiologically descriptive terms.

111. General and Special Sensations. — There are various vague, indefinable feelings which are not referred to any particular portion of the body or to any external influence, and which we know as *general sensibility*. Sensations of fatigue, of restlessness, languor, weakness, and the like,

are of this sort. It is supposed that these are associated with the ramifying, interlacing plexuses of nerve fibrils in many parts of the body, and are not due to the excitation of specially constructed nerve endings.

Other sensations are more definite. We judge them to be caused by some influence acting upon particular parts of the body. What have long been known as the *five senses* are of this sort. But we now recognize, in addition to *touch*, *taste*, *smell*, *sight*, and *hearing*, other sensations apparently distinct from them, for which, in some cases at least, special nerve endings are provided, and special brain centers. These are sensations of *temperature*, of *pain*, of *hunger*, and of *thirst*, and the *muscular sensations* previously mentioned (§ 95).

112. The Sense of Touch. — Touch has been defined as *a sense of pressure referred to the surface of the body*. It is that sort of impression upon the nervous system which gives information respecting certain properties of bodies in contact with the skin or mucous membrane. Through it we learn whether an object is hard or soft, rough or smooth, and other particulars, some of which are also given by the sense of sight.

The *skin* is supplied with a variety of special adaptations which constitute it the *organ of touch*.

113. The Nervous Apparatus for Touch. — The thirty-one pairs of spinal nerves contain the fibers for feeling for the larger part of the body, as well as most of the motor nerve fibers supplying the muscles. It will be remembered that each spinal nerve arises by two roots from the spinal cord, one root containing *afferent* or *sensory* fibers, the other *efferent* or *motor* fibers. By the union of the two roots the nerve is formed, which thence contains both sorts of nerve fibers, as do its large branches.

114. In the neck, loins, and pelvis adjacent nerves interlace with one another to form a *plexus*, or network. In a plexus nerve fibers from two or more nerves are brought into connection in such a way that the parts of the body which receive nervous fibers from the plexus have communication with a greater number of nerve trunks and nerve centers, and may receive more complex impulses, than do those parts to which branches go from but a single nerve trunk. This is why these plexuses are so frequently found in connection with the nerves going to the limbs, where great complexity of motion and careful coördination are required.

The nerves of the skin form plexuses in the dermis. In some parts of the body these contain fibers from spinal nerves and also from certain of the cranial nerves. From these plexuses minute nerve fibers pass to the papillæ, which contain the tactile end organs.

115. Tactile End Organs. — *End organs* are those peculiarly formed nerve cells or groups of cells which receive and pass on the stimulus to which they are adapted. *Tactile end organs* are of several different forms.

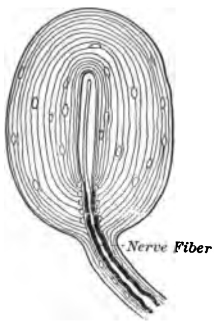


Fig. 50. — Pacinian corpuscle.

Pacinian corpuscles are found deep in the dermis, scattered along the fine nerve branches like buds on a plant. Each corpuscle consists of layers of delicate membrane within which is a single minute nerve fiber (Fig. 50). Another form of end organ, called the *touch corpuscle*, appears especially in the papillæ of fingers and toes, and is much smaller than the Pacinian corpuscle. The touch corpuscles are oblong masses, each containing a capsule

which receives a nerve whose fibers wind round and round the capsule before entering it (Fig. 51). Still smaller *end bulbs* are found in the skin, made up of nerve fibers ending in corpuscles in which the axis cylinder of the nerve terminates. All the tactile end organs are covered by the epidermis, so that the nerves themselves are not brought into actual contact with the external thing which they feel. If the cuticle were stripped off and pressure applied to a naked nerve ending, there would be, not a sense of touch with ability to judge of the properties of the body causing the sensation, but instead a sense of pain. Certain portions of the skin are more fully supplied with end organs for touch than are others, and the epidermis there is thinner, so that the sense of touch is more delicate. The tip of the tongue, the skin of the face, and the ends of the fingers are most sensitive. A pair of blunt-pointed compasses applied to the end of the tongue will be distinguished as two points even when they are separated by only one twenty-fourth of an inch, while they would be felt as but one point on the finger; and on the arm or back of the hand the two points much further apart would seem but one.

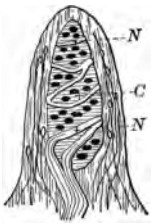


Fig. 51. — Touch corpuscle in papilla of the skin of the hand.
C touch corpuscle.
N nerve fibers winding around the corpuscle.

116. Sensations of Heat and Cold. — Sensations of touch arise from pressure, but through the skin we have, besides, sensations of heat and cold; that is, we perceive changes of temperature. It is thought that experiments indicate in the skin a separate set of end organs stimulated by heat, and another set which is stimulated by cold.

117. The Muscular Sense. — Still another sensation asso-

ciated with the sense of touch is that called the *muscular sense* (§ 95). By means of this sense we judge of the weight of a body. When we hold an object in the hand we feel its pressure upon the skin, and we also are conscious of a muscular effort to support its weight. We lift it up, move it from place to place, and by the amount of effort put forth judge of the weight of the object. In this process the muscles are involved as well as the cutaneous organs of sensation.

Again, we are conscious, even with our eyes closed, of the position of the whole body. (This we shall find to be connected with a certain part of the internal ear, § 179.) We are also conscious of the position of different parts of the body in relation to one another, and when we come in contact with external objects we perceive not only the pressure from them affecting our organs of touch, but also the pressure which we exert by muscular contraction upon them; that is, the resistance to our movements which is exerted by external things. It is sometimes said that we have a "sense of effort" (or weight), a "sense of position," and a "sense of movement," but all these are included in the more general term, *muscular sense.*

118. Pain.—It is not yet fully determined whether the sensation which we call *pain* is due merely to excessive stimulation of the already known sensory organs, or is a distinct sensation. Sometimes there is disease of sensory tracts which destroys sensitiveness to pain, though the sense of touch is unaffected. It may be that the nerve fibers already referred to, which, distributed everywhere through the body, constantly convey to the brain impressions of which we are usually hardly conscious, and which we call impressions of general sensibility, are the channels

by which a sense of pain is conveyed when they are more strongly stimulated.

119. Path of a Touch Impression. — Let a touch corpuscle be stimulated by pressure, and what follows? (Fig. 52.)

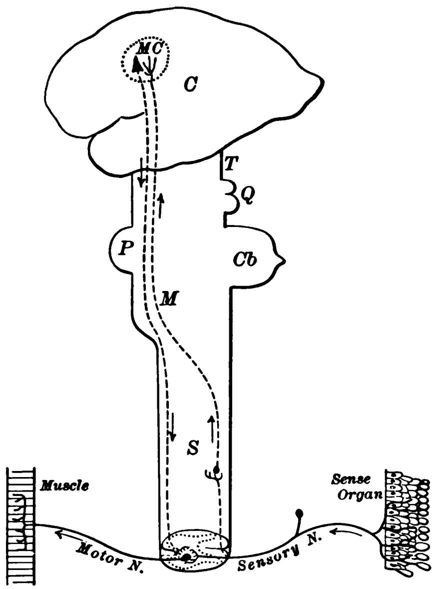


Fig. 52. — Diagram of the path of a touch impression.

The dotted lines show the path when the impulse ascends to the brain, exciting consciousness, and through the motor center (*MC*), producing voluntary motion.

The cells of the end organ communicate the impulse to the afferent nerve fibers passing from the touch corpuscles to the nerve distributed to that part of the skin. The sensory nerve fibers may run through more than one nerve plexus and through ganglionic nerve centers. There may be several breaks in the path, where the original impulse is handed over from one fiber to another, or passes from cell to cell, or from fiber to cell; but the impulse finally reaches the spinal cord (except when a cranial nerve conveys the impulse), through a *posterior nerve root*, and the cells of the gray matter of the cord are stimulated.

But there is yet no sensation, even though by the reflex action of the cord a motor impulse may be sent out by an

anterior root and certain muscles may be made to contract. The brain must be stimulated before there can be perception of a nervous impulse. Through the nerve fibers which run from cells of the gray column into and up the white columns of the spinal cord, the nervous impression must be carried on till it affects the special nerve cells in the particular portion of the brain set apart for receiving the particular kind of nervous stimulus from the particular part of the body. Then *sensation* results, and through the influence of the will, carried along the *efferent* motor fibers, motion may be produced in the voluntary muscles, and a great variety of acts may take place in consequence of the stimulation of the sensory organs in the skin.

Demonstrations and Experiments

28. *Simple Epithelium.* — In connection with the subject of the skin, the general structure of epithelium may be profitably illustrated. Where frogs are kept in captivity, excellent examples of simple epithelium can be obtained from the moulted skins, for examination with the microscope.

29. *Ciliated Epithelium.* — If the roof of a living frog's mouth be scraped with a scalpel and the débris thus obtained be mounted in normal salt solution on a slide, there can be found, on examination with the microscope, many cells which show cilia moving actively.

30. *Squamous Epithelium.* — Scrape the inside of the cheek with a scalpel, mount the débris in water on a slide, and examine with the microscope. Irregular flattened plates can be distinguished, singly or in groups. In most of them the position of the nucleus can be discerned.

31. *Epithelium in Section.* — If possible, some prepared microscopical sections of various kinds of epithelium should be studied by the class. Sections of the wall of the digestive tract, of the trachea, of blood vessels, etc., furnish excellent examples.

32. *Section of the Skin.* — Specially prepared sections of human skin can be purchased. Usually such sections contain hair follicles, sweat glands, and oil glands.

33. *The Epidermis.* — Observe that with a needle a portion of the outer skin may be removed without pain or flow of blood. If the hands be washed in warm water and then dried, on rubbing them together briskly, portions of the dead scaly epidermis will be removed.

On the palm of the hand the epidermis is seen to be thrown up in a series of curved parallel ridges. The latter are caused by the projections of the papillæ of the underlying dermis. On examination with a lens, large numbers of the minute openings of the sweat glands may be seen on the ridges of the epidermis.

34. *Discrimination in Touch.* — Find the least distance at which the points of a pair of blunt-pointed compasses can be distinguished as two points when applied to the skin of the arm. Repeat the same experiment on the back of the hand, the forehead, the finger tips, and the tip of the tongue. In this way a region of greatest sensitiveness can be distinguished.

35. *Location of Touch.* — Ask a person to close his eyes, touch some part of his body with a pencil, and ask him to indicate the same point with another pencil, immediately afterward. He will probably make some errors. The experiment may be made more interesting by repeating the trials, taking the measure of each error and averaging the errors. By repeating this experiment on a number of persons, some very interesting results may be obtained and tabulated.

36. *Aristotle's Experiment.* — Cross the middle over the index finger so that the tip of the middle finger is on the thumb side of the index finger. Place between the two a marble or other small object. A sensation of two objects will result, especially if the fingers be moved.

37. *Delicacy of Touch.* — With small weights of pith or cork, find the least pressure that is perceptible on the skin of the arm and tips of fingers. The weights may be applied by lowering them upon the skin by means of delicate silk fibers attached to them. The surface which is applied to the skin should have the same area in all the weights, and care should be taken that the weights do not move after touching the skin. The person experimented upon should keep the eyes closed while the weights are being applied. The weights should also be applied to the forehead, temples, lips, and tongue. The main purpose of this experiment is to determine the regions of the skin most sensitive to contact.

38. *Hairs as Organs of Touch.* — If the weights used in the preceding experiment be applied to regions of the skin possessing hairs, it

will be found that a weight touching a hair may be felt, even though its contact is not perceived when it is applied directly to the skin.

39. *Estimation of Weight by Sense of Pressure.* — Rest the back of the hand upon some easy support, and place on the palm a small wooden or pasteboard disk. Upon the latter place different weights. Find the least difference in weight that can be detected. A great variety of weights can be obtained by loading empty cartridges with shot to any desired extent. If the cartridges are all of the same size, then the person experimented upon can not estimate the weight by sight. Several pupils should be experimented upon, to show variation in acuteness of pressure sense.

40. *The Muscular Sense.* — Modify the preceding experiment by having the weights lifted instead of simply allowing them to press on the hand. It will be found that smaller differences can be detected than by pressure alone. Demonstrate that a weight lifted slowly seems heavier than one lifted rapidly.

41. *Sensations of Heat and Cold.* — That there are in the skin two distinct varieties of nerve endings of the temperature sense can be very easily demonstrated by carefully stimulating any certain area of the skin with hot and cold bodies. Let a square be marked off with ink, on the forearm, and a pointed brass rod be heated and then carefully drawn across this square in parallel lines in various directions. Here and there a sensation of heat will appear distinct from the sensation of contact. The hot spots should be marked with ink dots, as they are recognized. Then in a similar way go over the square with a cold brass rod. Cold spots will occasionally appear, in almost every case distinct from the hot spots. The cold spots should be marked in ink of a different color from that of the hot spots.

CHAPTER VII

TASTE AND SMELL

120. The mucous membrane of the mouth contains the nerve endings which are affected by *taste stimuli*. The special taste organs are found chiefly in the *papillæ* of the tongue and the palate.

Fig. 53. — The tongue.
K filiform papillæ. *I* fungiform papilla. *L* circumvallate papilla.

121. **The Tongue** is a mass of striped muscular tissue, with fibers running in various directions, the whole organ being covered with mucous membrane (Fig. 53). The *papillæ* of the tongue are much larger than those of the cuticle and are plainly visible to the naked eye. In some animals, as the dog and cat, they are very prominent and have horny spines

:h give a marked roughness to the surface. On the t and sides of the tongue the papillæ are generally · and slender, and are efore called *filiform illæ*. Others with ,d, spreading, mush-a-shaped tops are scat-d among the filiform llæ and are called *fun-m papillæ*. A third ety, the largest of all, is

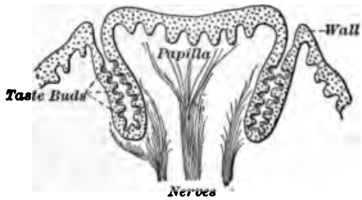


Fig. 54. — Section of circumvallate papilla.

circumvallate papillæ (Fig. 54). These last are only t or ten in number, and are seen at the back of a man's ;ue, in two rows converging to a point backward.

2. **Taste Buds.** — In the walls of the circumvallate and ome, at least, of the fungiform papillæ the end organs for taste have been found. These consist of a number of overlapping epithelial cells, like the leaves of a bud (Fig. 55). The innermost core of the bud is a number of slender, closely packed cells terminating in fine, stiff spikes which project at the surface of the bud. These are the *taste cells* and are the essential part of the *taste buds*. Around these cells the nerve filaments from certain branches of the ninth pair of cranial nerves (the *glossopharyngeal*) end in brushlike expansions.

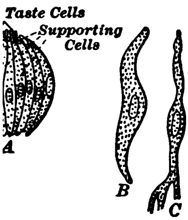


Fig. 55.
lated taste bud, from ose upper free end ject the ends of the te cells.
pporting or protect- : cell.
ste cell.

ranches from the fifth cranial nerve (the *trigeminal*) also distributed to the tongue, and are believed by ny physiologists to be concerned in taste.

Taste buds are affected so as to distinguish different tastes only when the substances submitted to them are in solution. The effect is increased by friction between the mouth and the tongue.

123. Classification of Tastes.—Tastes are of four sorts: (1) sweets, which are best appreciated by the tip of the tongue; (2) sour, or acid tastes, perceived best by the side of the tongue; (3) bitter tastes, most affecting the back of the tongue; (4) salts.

It is believed that separate taste buds are provided, one sort being stimulated only by bitter substances, one by sweet, one by sour, and one by salt. Some substances taste sweet at the tip of the tongue and bitter at the back of it, because they are able to stimulate two sorts of taste buds, but one kind of buds recognizes only a sweet taste, the other only a bitter taste.

124. Flavors.—We are accustomed to say and to think that we taste a great variety of flavors in our food; but physiologists tell us that we really taste only the four flavors mentioned above, while others are recognized by the sense of smell. This may be tested by holding the nostrils closed by the fingers while different kinds of food are eaten. An onion will not *taste* different from a potato, though one would be known from the other by its texture.

125. The Sense of Smell.—The organ for receiving impressions from the minute particles called *odors* is the mucous membrane lining the upper part of the nasal cavity.

126. The Olfactory Nerves are the first pair of cranial nerves. They spring from the *olfactory lobes*, which are prolongations of the hemispheres of the brain (Fig. 19, p. 29) and extend forward from the base of the cerebrum. Branches of the nerves of smell are distributed from the olfactory *bulbs*, in which the olfactory lobes end,

to the mucous membrane of the nasal passages (Fig. 56), where the fine filaments of the nerve end in delicate rod-shaped cells crowded in among the columnar cells of the epithelium lining the nasal passages (Fig. 57).

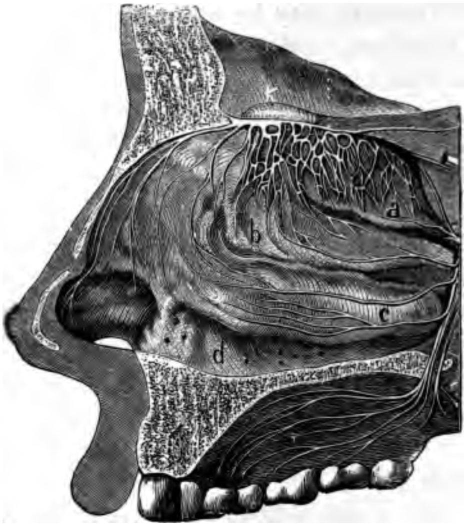


Fig. 56. — Section of nose, showing outer wall of right nasal cavity.

a, b, c, d interior of nose.
K olfactory bulb, below which are seen the nerve fibers spreading out in the mucous membrane.

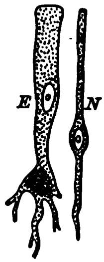


Fig. 57. — Cells from olfactory membrane.

E epithelial cell.
N nerve cell.

127. An Olfactory Impression. — Odors are usually carried to the membrane of the nose by means of the atmosphere, but they must be dissolved or suspended in liquid before they can affect the end organs for smell. Hence the glands of the olfactory membrane lining the nasal passages, whose secretions keep the surface always moist, are important subsidiary organs. As the air is brought to the membrane in ordinary breathing, one is able to perceive various odors when moderately strong. By what is called "sniffing" the air is drawn into the upper as well as the lower nasal chambers, and more of the

odoriferous particles reach the olfactory cells. Thus one is able to examine more fully the odors of the air, and several different "smells" may be sometimes distinguishable at once. Usually the odors reach both nostrils at the same time and two impulses are conducted along the two olfactory nerves; they are, however, fused into one sensation. If different odors are brought at one time to the olfactory cells of the two nasal passages, one sensation sometimes destroys the other; sometimes first one and then the other odor is perceived; in any case there is but one sensation.

128. Other afferent impulses than thôse of smell may arise in the nasal membrane. A very pungent substance, such as ammonia, causes sensation distinct from smell, sensation which is found to belong both to parts of the nasal membrane on which the olfactory nerves ramify and also to other portions.

A very small quantity of odoriferous material is sufficient to excite the sensation of smell. A very minute particle of musk, for instance, will fill a large room with its odor, and that for an indefinitely long time.

The end organs of the olfactory nerves are soon exhausted, and sensation dies out. We soon cease to notice the odors in a room, though we may have thought them overpowering on entering. Many animals are much more liberally endowed with the power of detecting and discriminating odors than is man.

129. Path of an Olfactory Impulse. — The olfactory cells in the epithelium of the nasal passages send a process to the surface of the mucous membrane, and another inward (Fig. 57). The latter process of each cell ends in fine spreading fibrils which mingle with similar brush-like fibrils from a deeper layer of nerve cells in the olfac-

lobe. These deeper cells send axis cylinder processes ıd along the olfactory tract to different centers in ray matter of the cerebrum. ɘ centers lie in the temporal back of the eye (Fig. 58). e olfactory nerves have a exceptionally direct from external or *peripheral* end ıe brain center in which rise. Just what is the ɜction between this fact the other often observed that stronger mental asso- ›ns cling about sensations ıell than about almost any external impressions, it is asy to say.

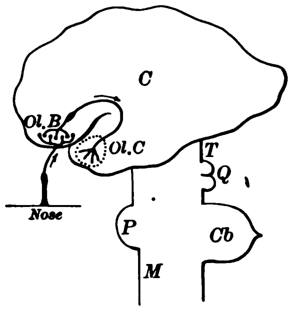


Fig. 58. — Diagram of the path of an olfactory impulse.

The impulse passes from the olfactory cells of the nose to the olfactory bulb (*Ol.B*), and thence to the olfactory center (*Ol. C*) on the inner side of the temporal lobe of the cerebrum.

'ong reflex nervous action results from excessive stimulation of the olfactory ›s, as when a person faints in consequence of inhal- ertain odors.

›. **Effects of Alcohol upon Taste and Smell.** — The ha- l use of drinks containing alcohol, of tobacco, and of strongly flavored foods is found to dull the sense of and by alcohol, at least, the olfactories are rendered ›cute.

DEMONSTRATIONS AND EXPERIMENTS

The Tongue. — By the aid of a hand mirror the pupil can distinguish the filiform and fungiform papillæ, on his own ɘ. The circumvallate papillæ lie so far back that it will be more convenient to demonstrate them on the tongue of one of ›mestic animals (dead).

43. *Varieties of Tastes.* — Wipe the tongue dry and place on its tip a crystal of sugar. It is not tasted until it dissolves. Place a crystal of sugar on the tip and another on the back of the tongue. The sweet taste is more evident at the tip. Repeat the process, using a strong solution of quinine sulphate dissolved in water by aid of a little sulphuric acid. The bitter taste is most pronounced on the back of the tongue. In a similar way determine where acids and salts are tasted, using a 1 per cent solution of acetic acid and a 10 per cent solution of common salt respectively.

44. *Organs of Smell.* — The turbinated processes of the human ethmoid and maxillary bones, or those of some of the domestic animals, should be accessible to the pupil for examination, as they show how a great deal of surface in a small space is provided for the olfactory membrane. The teacher should perform such dissections upon the head of some one of the domestic animals as to show the olfactory epithelium, the exterior nasal passages, and the posterior passages opening into the pharynx.

45. *Combination of Taste with Smell.* — Close the nostrils, shut the eyes, and try to distinguish by taste alone between an apple, a potato, and an onion. Chew a grain of roasted coffee and notice how nearly tasteless it becomes when the nostrils are closed.

46. *Fatigue of Smell.* — For several minutes smell continuously of a piece of camphor gum, breathing in through the nose and out through the mouth. The intensity of the smell becomes much lessened. But if some other odoriferous substance, as clove oil, is brought near the nostrils, it will be found that the fatigue is only for the odor of camphor.

CHAPTER VIII

THE EYE AND THE SENSE OF SIGHT

131. By means of touch, taste, and smell the brain perceives external objects through actual contact between particles of matter from the objects perceived and the human organism. But we need to be able to acquire knowledge of the properties of objects at a distance from ourselves. The sense of smell does indeed bring to us limited information respecting some classes of objects at no great distance; but it is by means of the eye and the ear that we gain our most valuable knowledge of the universe, and through these that we enjoy the most refined and elevated of all our pleasures.

132. Vision. — When rays of light fall upon a nervous apparatus so made as to be affected by that stimulus, and the impulse is carried by a nerve to the nerve center for vision, there results the sensation of sight. Some animals possess a simple arrangement for vision, consisting of only three parts. Certain modified parts of the epidermis are stimulated by the light, nerve fibers carry the impulse to the nerve center, and light is perceived. Man, however, is provided with organs of vision of elaborate and complex structure.

133. Light. — All space is believed to be filled with an extremely thin, perfectly elastic medium called *ether*, in which atoms, molecules, and masses of matter are immersed

as fishes are immersed in the sea. Of this ether little is known, but it is supposed to transmit energy by waves. The energy resident in vibrations of the ether is called *radiant energy*, and it receives special names according to its special manifestations. For example, when it raises the temperature of objects which receive it, it is called *radiant heat;* when it causes chemical changes, it is called *actinic energy;* in another form it is known as *electricity;* when it affects the eye we call it *light.* All these forms of energy extend in straight lines from the points of origin. Every visible object sets up waves in the ether going in every possible direction. Many millions of these waves are produced in a single second.

134. Color. — Some light waves give to the eye the sensation of red color; these are the longest of the light waves perceived by the eye. Others give us the perception of violet color; they are the shortest. Between them in length are the waves of all the other colors. A union of these many colors produces white light.

135. The Spectrum. — When a slender beam of sunlight is allowed to pass through a small hole, and then through a glass prism into a darkened room, the rays of light falling upon a screen are seen in an oblong band of light of many colors arranged as we see them in the rainbow. This band of colors is called a *spectrum* (Fig. 59).

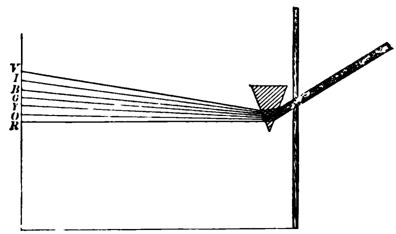


Fig. 59. — Separation of the rays of a beam of light by a prism.

136. Refraction. — The separation of colors by the prism *is due to two* facts. First, whenever a ray of light passes

obliquely from one medium into another of different density, its direction is changed, the ray is bent, or refracted, we may say. In passing from the atmosphere through the prism, the ray of light is twice turned from its original direction. Second, different colors are refracted in different degrees; red rays, or those having the longest waves, are bent least; the violet rays, those having the shortest waves, most of all; and the colors between vary in this respect in the order of their arrangement in the rainbow.

137. Images formed by Lenses. — A *lens* is a transparent medium, having at least one curved surface. Rays of light from any point passing through a lens are bent either toward each other or more widely apart, according to the arrangement of the surfaces of the lens. When they are bent toward each other they may be brought together at a point called the *focus*. If the focus is allowed to fall upon a screen or other suitable surface, an accurate image of the object from which the rays come is produced (Fig. 60). By using a properly prepared plate the photographer fixes this image and produces a permanent picture.

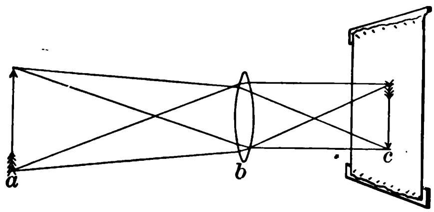


Fig. 60. — Diagram of the formation of an image with a lens.

a an object sending off light. *b* lens. *c* image of the object *a*.

138. The Nervous Apparatus for Vision may be briefly said to consist of: (1) the membrane of the eye, called the ***retina***, which receives the end filaments of the optic nerve; (2) the *optic nerve;* and (3) the *visual center* in the brain, which receives the stimulus conveyed by the optic nerve

and gives rise to the consciousness of sight (Fig. 61). Nerve fibers are also distributed to the numerous muscles of the various parts of the eye and its accessories.

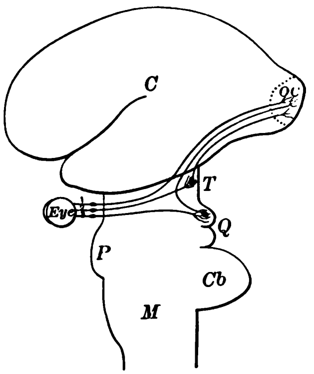


Fig. 61. — Diagram of path of optic impulse.

Three courses are possible: (1) directly from cells of retina to the visual center (*OC*); (2) through a relay in the optic thalamus (*T*); (3) through a relay in the anterior corpora quadrigemina (*Q*).

139. Nerves of the Eye. — The second pair of cranial nerves are the *optic nerves* (Fig. 19, p. 29). The third pair go to four of the muscles which move the eyeball, and are called the *oculomotor* nerves. The fourth and sixth pairs also supply muscles of the eyeball. From the fifth pair of nerves (the *trigeminal*) are sent branches to the lachrymal glands and the eyelids.

140. Course of the Visual Impulse (Fig. 61). — Rays of light falling upon the retina produce certain changes (chemical or other) in or about the peculiarly shaped nerve cells called *rods* and *cones*. These changes excite a nervous impulse which is conducted by the minute nerve fibers from the rods and cones (the end organs of vision) along the optic nerves which, after passing through the opening in the back of each eye socket, unite at what is called the *optic commissure*. Here many of the nerve fibers cross, but some from each eye pass on to the nervous center of the same side; so that if the centers of vision on one side were destroyed, there would still be sight in both eyes. This crossing of the optic nerve fibers is called the *optic chiasma* (Fig. 62).

Beyond the junction of the optic nerves the course of a visual impulse is called the *optic tract*. Some of the fibers run directly to the visual center from the retina, others pass to the corpora quadrigemina and other centers before reaching the cortex. The gray matter of the brain is regarded as the seat of sense perception, and the sense of sight is believed to be located in certain groups of cells in the hinder part of the cerebrum.

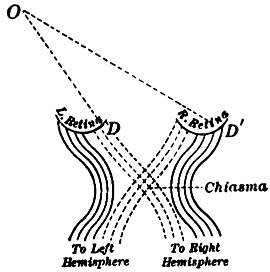


Fig. 62. — Diagram of optic chiasma.

Rays from O, falling on the similar regions of the retina (D, D'), give rise to impulses passing to the same half of the brain.

141. The Eye. — Something more than the nervous apparatus above described is needed to enable one to perceive a definite image of a distant object. Light falling upon the general surface of a retina with its conducting nerves and nerve centers would result only in perception of light and of color. But in the eye, lying in front of the retina, are certain refracting media which act as lenses to converge the rays of light so that only points of the retina are affected by them; that is, the rays are brought to a focus, and an image of the object from which the rays come is produced as in a photographer's camera. The eye lies in a pyramidal cavity, called the *orbit*, having its apex directed inward and backward.

142. The Coats of the Eye. — The eye is a nearly spherical sac about one inch in diameter, made up of a firm wall of tissues called the *coats of the eye* (Fig. 63). The outer of these, composed of connective tissues, is opaque except at the center of the front of the eye, where it becomes transparent and is called the *cornea;* the remainder of this

outer coat is called the *sclerotic coat*, and forms the "white of the eye." At the back of the eyeball the optic nerve pierces through this coat to reach the *retina*. Both the cornea and the sclerotic coat on the front of the ball are covered with a thin layer of modified mucous membrane, called the *conjunctiva*, which is folded back to form the lining of the eyelids.

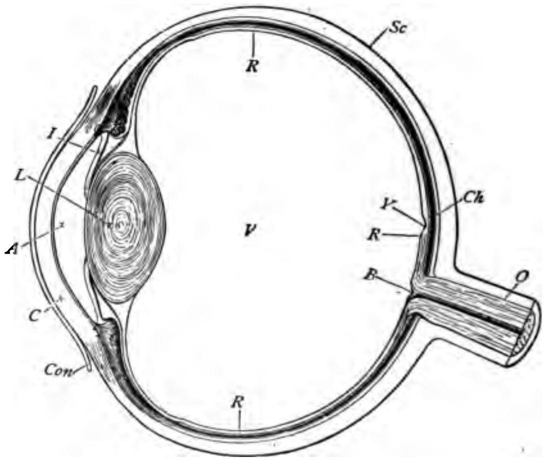


Fig. 63. — Cross section of the eye.

Sc sclerotic coat. *Ch* choroid. *O* optic nerve.
C cornea. *I* iris. *B* blind spot.
con conjunctiva. *R* retina. *Y* yellow spot.
L lens. *A* anterior chamber, filled with aqueous humor.
V posterior chamber, filled with vitreous humor.

A second coat of the eyeball consists of the *choroid*, made up largely of blood vessels and loose connective tissue, and containing in the inner layers a dark pigment. Just before it passes into the *iris* — which is that part of the choroid forming the colored ring in the front of the eyeball, pierced by the pupil — the choroid is laid

iating folds called the *ciliary processes*, which are ›vered by the pigment.

The *iris* is a ring of plain, or involuntary, mus- tissue. Its circular fibers by contracting narrow ːpil, while its radi- muscular or elastic by their contrac- dilate the pupil the circular muscle xed. Fibers from ıird cranial nerve istributed to the ır muscle, and oth- rom the sympa- nervous system .so found in this ɜ of the iris. The nt of the iris gives we call the "color eye." The *pupil* ıply an opening ʒh the iris into the ːhamber beyond.

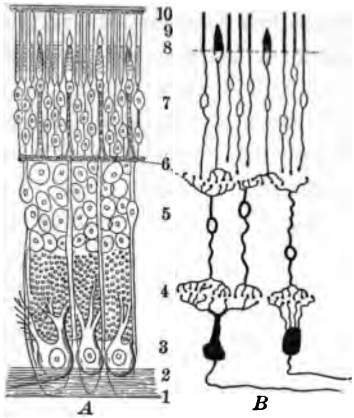


Fig. 64. — Section of the retina.

A diagram of the structure of the retina as seen with the compound microscope.
B the essential nervous elements of the retina as demonstrated by the Golgi method.
1 internal limiting membrane.
2 nerve-fiber layer.
3 nerve-cell or ganglion-cell layer.
4 inner molecular layer.
5 inner granular layer.
6 outer molecular layer.
7 outer granular layer.
8 external limiting membrane.
9 rod-and-cone layer.
10 pigment-cell layer.

The Retina.—The ɔf the coats of the the *retina*. This nposed essentially end fibers of the nerve and nerve which, with a supporting skeleton of connective tis- orm a thin membrane lying loosely upon the choroid ›vering it as far as the ciliary processes. The retina complex to admit of full description here. Though

only about one fiftieth of an inch in thickness at the point opposite the pupil, where it is thickest, it consists of ten different layers (Fig. 64). Beginning with the side toward the center of the eyeball, the first layer, called the *internal limiting membrane*, is in contact with the vitreous humor which fills the largest cavity of the eye (§ 146), while the tenth, or *pigment-cell layer*, is next the choroid.

In the second layer, that of the *optic nerve fibers*, the minute filaments of the optic nerve are distributed. From this second layer they turn backward to enter the deeper layers of the retina.

The third layer is that of *ganglion cells*. They are large nucleated cells, whose axis cylinder processes are continuous with the optic nerve fibers of the second layer.

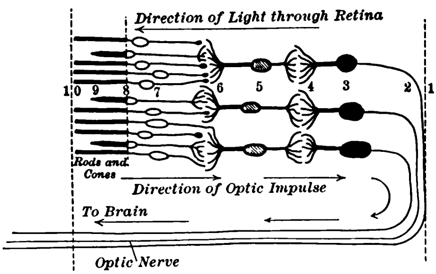


Fig. 65. — Diagram of a section of the retina. Showing that the rays pass from the anterior to the posterior parts of the retina to reach the rods and cones. From the latter the optic impulse passes to the anterior parts of the retina, and thence by the optic nerve fibers through the posterior parts to the brain.

In the ninth layer are found nerve cells of peculiar shapes, called *rods* and *cones*. There are more *rods* than *cones*, three or four rods usually lying between two cones. It is understood that in these cells arises the nervous impulse which results in vision.

From the pigment-cell layer extends a thick fringe to support the outer ends of the rods. Many of the rays of light which fall upon the retina are absorbed by the pigment, only a small part of the rays being reflected back

through the pupil. Hence the interior of the eye usually looks black.

145. The Yellow Spot and the Blind Spot (Fig. 63). — The retina is not equally sensitive to light over its whole surface. Only upon a single spot, about one twenty-fourth of an inch in diameter, are perfectly definite outlines of images formed. This is called, from its color, the *yellow spot.*

About one tenth of an inch from the inner side of the yellow spot is the optic disk, or *blind spot*, an elevated surface where the optic nerve fibers enter the eye. These are conducting nerve fibers only, not stimulated by light, and that spot is therefore blind.

Delicate fibers from the optic nerve run straight to the yellow spot. Here the layer of ganglion cells is much thicker than elsewhere, and in the rod-and-cone layer of the yellow spot no rods, but cones only, are found.

In the very center of the yellow spot is a colorless depression, or pit, from which the various layers of the retina have nearly disappeared, leaving only the rod and cone layer. This is the point of most acute vision, the spot upon which the image falls when, wishing to see with the utmost distinctness, we look "straight at" an object.

146. The Lenses (Fig. 63). — The refracting media of the eye are four in number. (1) The *cornea* has already been defined. (2) The *crystalline lens* is a transparent, double-convex body about one third of an inch in diameter and one fourth of an inch thick, lying just back of the pupil and kept in place by a sheet of transparent membrane called the *suspensory ligament* attached to the circumference of the lens and to the ciliary processes. (3) The space between the iris and the cornea, called the *anterior chamber*, is filled with a thin fluid like water, called the

us humor. (4) The larger cavity of the eyeball, ıd the iris and the crystalline lens, called the *posterior ıber*, is filled with a transparent, semifluid, jellylike stance called the *vitreous humor*.

47. The Muscles of the Eyeball and their Nervous Supply ig. 66). — Each eye is moved by six muscles, four of which are straight and two oblique. The straight, or rectus, muscles have one end attached to the margin of the opening in the orbit through which the optic nerve and accompanying blood vessels pass, while the other is inserted into the eyeball. The *internal rectus* muscle, inserted on the nasal side of the eyeball, turns the ball inward; the *external rectus*, inserted on the outer or temporal side, turns it outward. The *superior rectus*, inserted on the upper and forward side, pulls the eye upward; the *inferior rectus*, inserted on the under and forward part of the ball, draws it down.

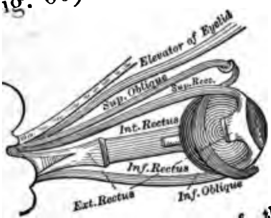


Fig. 66. — **Muscles of the right eye.**

The remaining muscles are called the *superior* and the *inferior oblique*, and they unite with the straight muscles to move the eyeballs inward and upward, inward and downward, outward and upward, outward and downward, and to produce a measure of rotation upon an axis. The *superior oblique* muscle arises near the straight muscles in the edge of the orbit. Near its forward end it narrow into a tendon which passes through a ring of fibrocartilag attached to a notch in the frontal bone which bounds th front and upper margin of the orbit; the end of the tend is then inserted into the upper side of the eyeball. T cartilage ring acts as a pulley to change the direction

the muscular action. The *inferior oblique muscle* arises near the front of the orbit and at its inner side, whence it passes under the ball and nearly halfway round it, to be inserted into the back part on the temporal or outer side.

148. The muscles of the two eyes act simultaneously so that the two retinas may receive images from the same objects at the same time and upon corresponding portions of their surfaces. The external rectus of the right eye contracts at the same time as the internal rectus of the left eye, turning both eyes to the right, and *vice versa.* All these muscles are supplied with nerves from the third pair of cranial nerves, except the superior oblique, which is supplied by the fourth, and the external rectus, which is supplied by the sixth.

149. The Ciliary Muscles and Nerves. — Besides the muscles which move the eyeball as a whole, certain muscles within the eyeball have to do with vision. These are the muscles of the iris, which vary the area of the pupil, and the *ciliary muscles*, which accommodate the eye for different distances by altering the shape of the lens, as will be explained a little later. The *ciliary nerves* supply these muscles. They are composed of fibers from the third and fifth cranial nerves with others from the sympathetic system. Branches from the ciliary nerves are distributed also to the cornea.

150. Other Appendages of the Eye (Fig. 67). — Each eyeball lies in its orbit upon a soft cushion of fat, and the cavity also contains connective tissue, blood vessels, and nerves. The front of the eye is protected by the *eyelids*, which are two folds of skin stiffened by thin plates of fibrous tissue. Along the edges of the lids arise rows of curved hairs, called *eyelashes*, which serve to protect the eye from dust, and furnish a slight shade. On the inner

edges, in little grooves, are minute glands from which an oily secretion flows to the free edges of the lids and prevents their adhesion when closed. Above the orbits the thick ridges set with hairs, called *eyebrows*, also serve to shield and shade the eye.

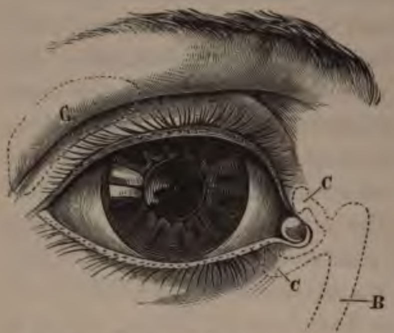


Fig. 67. — Front view of the right eye, showing the position of the lachrymal apparatus.

G lachrymal gland.
CC upper and lower lachrymal ducts.
B naso-lachrymal duct.

In a depression in the upper and outer part of the orbit lies the *lachrymal gland*, with ducts opening on the inner surface of the upper lid. It secretes a watery fluid designed to lubricate the surface of the eyeball. When stimulated by the irritation of the mucous membrane of the eye, the nose, or the mouth, or by strong mental emotion, the lachrymal fluid becomes excessive, and is called *tears*. Canals or ducts placed at the inner angle of the eye carry off the ordinary supply of lachrymal fluid to the nasal passages. Branches from the fifth (trigeminal) cranial nerve supply this gland and send fibers also to the eyelids and to inner portions of the eyeball.

151. The Eye as an Optical Instrument. — As has been said, the eye is like a photographer's *camera obscura*, the various parts of which all have to do with the production of distinct images of external objects upon the back portion of the box; that is, in the camera upon the ground *glass screen*, in the eye upon the nervous membrane called

the retina (Fig. 68). In the camera a glass lens serves to bring the rays of light to a focus upon the screen. In

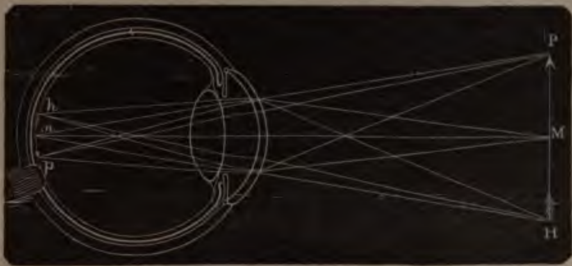


Fig. 68. — Formation of an image on the retina.

the eye the cornea and the crystalline lens accomplish the same object.

152. Accommodation (Fig. 69). — The camera is provided with an apparatus for changing the distance of the lens from the sensitive plate or screen, so that light from objects at different distances may be focused. The eye is likewise supplied by means of what is called *accommodation*, which is the power of the eye to adjust itself to objects at different distances. This power is due primarily to the variable shape of the crystalline lens. In the camera, the lens and the screen which receives the image are moved nearer together or farther apart in order to change the focus. In the eye the same object is gained by changing the convexity of the lens itself. This is accomplished by the contraction and relaxation of the *ciliary muscle*, which lies just beyond the outer margin of the iris in the front part

Fig. 69. — Diagram showing how the lens changes its form.

of the choroid coat. It consists of plain muscle fibers, whose nervous supply comes from the third cranial nerve. The ciliary muscle is attached to the ciliary processes, and these to a membrane called the suspensory ligament. This ligament is secured also to the circumference of the lens in such a way that when the eye is at rest it is in a state of tension, which causes it to pull upon and slightly flatten the lens. This keeps the eye at the focus necessary for seeing clearly objects at a distance of perhaps twenty or twenty-five feet. When the eye is directed to a nearer object, the fibers of the ciliary muscle contract, thereby drawing forward the ciliary processes, and thus lessening the tension on the suspensory ligament, and the elasticity of the lens causes it to push forward, or become more convex on its front surface. This shortens the focal distance, that is, causes the rays of light to converge more rapidly. The cornea alone is capable of forming distinct images, and the chief function of the crystalline lens seems to be that of accommodation.

153. Function of the Iris. — The iris (Fig. 63) is an adjustable curtain, designed, by narrowing the pupil, to cut off a portion of the light which might render the image confused, and to prevent too strong a light from entering the interior of the eye. This change in the size of the pupil is effected by the contraction and relaxation of its muscular tissue, under control of the ciliary nerves.

154. Inversion of Images (Figs. 60 and 68). — As in a camera, so in the eye the image formed is *inverted*. The rays of light cross in being brought to a focus, so that the picture of a man, a house, or a tree on the retina is upside down, and also much smaller than the object itself. The reason why we do not see objects inverted and reduced in size is because it is not the picture on the retina

that we see, but the object itself. Sensation is not in the eye, but in the brain, or in the mind acting through the brain. It is only by study and research that we learn the fact of the inverted image in the eye, and meantime we are accustomed to supplement our visual impressions by the use of our muscles and our organs of touch. The hand interprets the impression on the eye, and we learn to see objects in their true positions. We judge of their positions by the direction from which the light comes to the eye, and of their size by a variety of experiences which complete the impression given by sight. The figure on the retina has little or nothing to do with those judgments.

155. Seeing with Two Eyes. — Two images of one object are formed on the two retinas, and two optic nerves and tracts convey the impression to the two opposite sides of the brain. Why, then, do we not see two objects? Here again we must remember that our perceptions are never simple, due to the action of a single organ and an isolated set of nervous connections. Probably in every act of perception the nervous system acts as a whole through the intricate interlacing of nervous fibers and the close connections of the cells in the various nerve centers. An impression upon one set of end organs is supplemented and corrected by a great number of familiar perceptions of diverse sorts brought before the mind by memory, so that the resulting judgment is an act too intricate and complex to be disentangled. We come to think of the object as we know it from all these combined impressions, and not from a single one of them. Perception is the result of association and experience combined with the physical processes involved.

156. Advantages of Two Eyes. — For perfect vision the retinal images must be formed upon corresponding portions

of the two retinas. The two pictures are not, however, identical. The right eye will see more of one side of an object than will the left, and the left eye will see more of the opposite side. This enables us to form more accurate judgments of form and distance than would be possible with only one eye. Then, too, one eye may be wholly destroyed and a person may still retain distinct vision.

157. Duration of Sight Sensation. — The impression made upon the retina by a flash of light remains for about one eighth of a second, so that if flashes of light follow one another at a shorter interval than that they appear as one continuous impression. Children make a circle of fire by whirling rapidly a lighted stick, and the spokes of a swiftly revolving wheel appear continuous. If one looks at the sun or other bright object and then closes the eyes, he will continue for an instant to see the object. These delusive appearances are due to the fact that the nervous impressions made by light upon the end organs in the retina remain after the removal of the rays which excite them.

158. Fatigue of the Retina. — While the retina is extremely sensitive it is also easily fatigued. If one looks steadily for a time at a bright object and then turns the eye away, he will still see the outline of the bright object, but it will be dark. This is because that part of the retina upon which the light fell from the bright body has become wearied and no longer responds to the stimulus of light. If the body looked at is of a bright yellow color, the figure seen when the eye is turned away will be blue, because the retina is no longer able to respond to the stimulus of yellow rays, but is affected by the rays of the complementary color.

159. Defects of Vision. — It is very common to see persons wearing lenses, or "glasses," to correct what is called

"shortsightedness," or "longsightedness." In shortsighted persons the rays which in normal eyes come to a focus exactly upon the retina meet at a point in front of it, so that no distinct image is formed. The eye is too long from front to back, and the difficulty must be corrected by using lenses which will carry the focus back to the surface of the retina (Fig. 70).

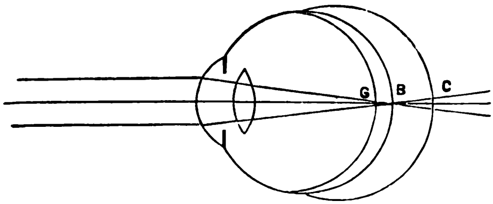


Fig. 70. — Diagram showing position of retina.
In natural sight (*B*). In far sight (*G*). In near sight (*C*).

Those who habitually use their eyes for seeing only objects near at hand are apt to become shortsighted. It has been found that children who have grown up in crowded parts of smoky London, with little opportunity for looking off long distances, are very often nearsighted. On the other hand, sailors and others accustomed to use the eye constantly for distant vision grow longsighted. Their eyes become shortened from front to back, so that the focus for ordinary vision is beyond the retina.

As persons grow old the eye usually becomes flattened on this axis, and glasses are needed to converge the rays of light more rapidly.

160. Squinting, etc. — The muscles of the two eyes act simultaneously so that the visual images are formed upon corresponding parts of the two retinas. But if the internal rectus muscle of one eye is paralyzed, or for some reason

the external rectus is too short, that eye will turn outw and defective vision will result. If the external rectu paralyzed, the person will be cross-eyed, or squint-ey Paralysis of either of the nerves distributed to the mus of the eye will result in abnormal action of those musc

161. Astigmatism. — Another defect, known as *astig tism*, is due to the irregular curvature of the cornea or lens or both. The eye may be more convex on one me ian than on others, so that rays of light falling upon part of the cornea (which is most frequently affected) brought to a focus at a different spot from the rays wl pass through other parts. Thus the image on the re is indistinct and the vision is blurred.

162. Color Blindness. — Some persons are unable to tinguish certain colors from eertain other colors. T are said to be *color blind.* Usually they differ f persons of normal sight in their inability to disting red from green. Sometimes only one eye is color bl the other being normal. The reasons for these phen ena belong to the abstruse subject of color sensat which is beyond the scope of this work.

The power to distinguish colors accurately is of g importance to those engaged in certain occupations, — example, to those employed upon railways, who are quired to undergo examinations which test their eye that particular.

163. Training of the Eye. — The eyes of the young 1 be easily trained by practice under a teacher's guida to see quickly and accurately, and to judge correctly a the size of objects, distances, etc. Such training is great value in all circumstances of life. It is ind more strictly a training of the mind than of the but may be fitly mentioned in this connection.

164. Care of the Eye. — More than some other organs, the eye depends for its healthy condition upon the general health of the system. If that is impaired, the eye is often weakened and liable to disease. The children of the poor, who are ill-nourished and inadequately clothed, oftener suffer from sore eyes and defective vision than do those in better circumstances. Living in filthy surroundings or rubbing the eyes with dirty hands often provokes diseases of the eyes and eyelids. Some forms of general disease — measles, diphtheria, scarlet fever, for example — are apt to leave the eyes for some time in a sensitive condition and in need of special care. Many eyes, even those of young children, are abnormal in respect to focalization, and the defect is often unsuspected until a child has endured much inconvenience or even suffering. Hence it is well for the eyes of every child to be examined by a competent oculist, and to have any defects corrected by suitable glasses. Children in school often suffer from severe headaches and appear dull at their studies simply because of easily remedied defects of vision.

165. Very strong light should never be allowed to enter the eye directly. When reading, sewing, writing, etc., one should sit so that the light will fall upon the work from the left side without shining into the eyes. But one should not read or write with direct sunlight falling upon the paper. Lamps should be provided with shades to shield the eyes, and the light should be steady, for a flickering light is exceedingly trying to the eye.

Too faint a light also strains the eye. One should not read or work by twilight, or by any light too dim to permit the book or work to be clearly seen at about eighteen inches from the eyes. Eyes may be made nearsighted

by carelessly acquiring a habit of holding books, etc., nearer than is necessary.

Reading while in a moving railway train or carriage is bad for the eyes, as the motion necessitates constant adjustment of the eyes to varying distance, and the power of accommodation is overstrained.

It is well when using the eyes closely to raise them often and look off to a distance, or to close them for a moment of rest.

Warm or tepid water is better than cold water for bathing the eyes. A compress wet in very hot water and laid over the eyes a few minutes at a time, several times a day, will cure slight inflammation, or relieve the weariness of the eyes after close application.

166. Effects of Drinks containing Alcohol upon the Eye.— Through its influence upon the nerves and the muscles, the continued and too free use of alcohol renders the eye unsteady and its adjustment uncertain ; the small blood vessels become dilated, and the eyes are blood-shot and often inflamed. The optic nerve is frequently affected, causing dimness of vision, and specific diseases of parts of the eye may result, such as cataract and disorders of the retina. The confirmed inebriate is the victim of diseased conditions in which the sight becomes untrustworthy. He sees horrible visions, frightful, venomous creatures appear to threaten him, and he is haunted by specters. Under his imaginary suffering he may become a raving maniac, and repeated attacks of the disease are likely to prove fatal.

Demonstrations and Experiments

47. *Dissection of the Eye.*—The eye of the sheep or of the ox should be studied. It may be examined fresh or after preservation

in one of the fluids used in hardening and preserving the brain (Ex. 6). First, the six muscles of the eyeball should be noticed and identified. To examine the internal structures an equatorial incision should be made about halfway between the cornea and the back part of the eyeball, thus dividing the eye into two parts. The structures thus made visible can be identified by reference to the corresponding parts of the text. If the teacher has any knowledge of histological methods, some excellent sections for study with the microscope can be prepared by hardening the eye of a rat or frog in Perenyi's fluid for two or three days, following with alcohols of increasing strength, infiltrating and embedding in celloidin, and sectioning on a microtome. Sections made horizontally through the entire eyeball, and properly stained, show not only the different coats and inclosed structures *in situ*, but the different layers of the retina, the entrance of the optic nerve, or blind spot, and the yellow spot. Similar sections can be purchased.

48. *Refracting Media.* — Refraction of light should be demonstrated by means of lenses of various forms. Especial attention should be given to the formation of images by convex lenses. The office of the lens of the eye can be shown by removing it from the eye of a recently killed animal and allowing the direct rays of the sun to be focused by it.

49. *Inversion of the Image on the Retina.* — This can be very easily shown by cutting away the posterior part of the sclerotic coat of a fresh ox eye, leaving the retina intact. Then on turning the cornea toward some bright object, as a candle flame, an inverted image of the object may be seen shining through the retina. The image appears much clearer if the eye is placed, cornea forward, in a tube of blackened paper.

50. *Model for demonstrating the Optical Properties of the Eye.* — At little labor and expense the teacher or pupil can construct simple apparatus that will illustrate many of the optical features of the eye. Prepare an oblong box from twelve to eighteen inches long, open on one side, and blackened within (Fig. 71). One end should be perforated in the center by an opening one half to one inch in diameter, to represent the pupil of the eye. A watch crystal can be fastened over the opening, outside, to represent the cornea. The amount of light admitted through the opening in the box can be regulated by means of paper diaphragms with different-sized perforations. Inside the box a reading

glass or other biconvex lens can be arranged on a support, so as to focus the rays of light admitted through the pupil upon a movable screen at the back part of the box. A serviceable ground glass screen can be made by rubbing a piece of ordinary window glass with emery powder and water. The box is left open on one side to permit observation and manipulation; but while experimenting the observer will find it necessary to exclude all light, except that which enters through the end of the box. This can be done by covering the box and the head of the observer with a black cloth. While with this apparatus one can illustrate

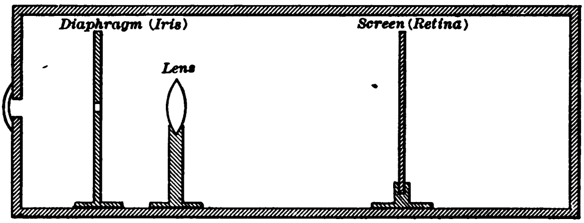


Fig. 71. — Apparatus for illustrating the optical properties of the eye.

most of the characteristic optical features of the eye, yet obviously it shows nothing regarding the functions of the aqueous and vitreous humors. It must be borne in mind, also, that in the eye accommodation for objects of different distances is brought about by changes in the form of the lens; here in the model by changes in the position of the lens. Shortsightedness and longsightedness can be very easily illustrated; also the means of correcting them by spectacles. Astigmatism can also be shown by holding in front of the artificial cornea a bottle with sides of unequal curvature, filled with water.

51. *Accommodation.* — Hold up the forefinger six or eight inches from the eye. Close one eye and look at the finger; it appears distinct, while objects across the room seem blurred. Look at these latter; they become sharply outlined, but the outline of the finger becomes indistinct. Notice that in accommodating for the near object there is a feeling of effort. Cease looking at anything in particular, and allow the eyes to come to rest. They will be found to be accommodated for distant vision.

52. Ask a person to accommodate his eye for distant objects. Then *look at his eye* from the side, while he adapts his vision to a near

object without moving the eyeball; the pupil and iris next the observer will be seen to move forward, owing to the increased curvature of the anterior surface of the lens.

53. *Movements of the Iris.* — In the preceding experiment the diameter of the pupil was smaller when the eye was accommodated for near objects, but dilated on changing to distant vision. Close one eye, and by aid of a mirror observe the size of the pupil of the other eye. Then open the closed eye; the pupil of the other eye contracts. Cover, with the hands, another person's eyes. On suddenly removing the hands, the pupils are seen to contract.

54. *Astigmatism.* — Close one eye and look at the radiating lines in Fig. 72. Notice which lines, if any, appear with the greatest blackness and distinctness. Try the other eye; do the two eyes agree? Look at the concentric circles of Fig. 72. In what portion of the figure, if

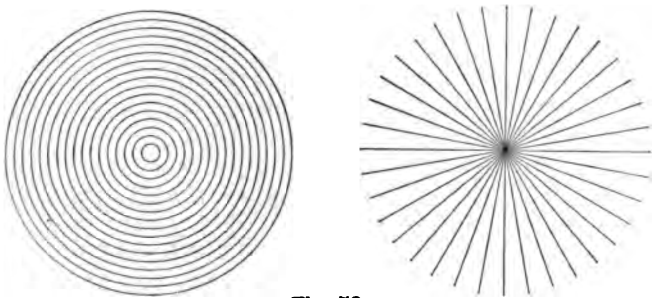


Fig. 72.

any, do the lines appear clearest? The teacher should obtain, from an optician, one of the charts commonly used in preliminary tests for astigmatism. With this he can detect some of the more pronounced cases of this optical defect among his pupils. It may happen, however, that very great defects cause little disturbance, since if the two eyes are astigmatic on different axes, one eye may correct the defect of the other.

55. *Nearsight and Farsight.* — These are common defects, and their causes should be illustrated by use of the apparatus described in Ex. 50. If the teacher will perform some of the simpler tests for optical defects of the eye (and almost any local optician will loan the necessary apparatus, and give instructions), he may not only inter-

est and instruct his pupils, but confer lasting benefits upon some of them in showing them their defects, and the means of correcting them.

56. *The Blind Spot.* — Close the left eye and with the right look intently at the cross in the following diagram (Fig. 73), holding the book about fifteen inches in front of the eye. Both cross and circle

Fig. 73. — Diagram to demonstrate the existence of the blind spot.

are seen. Gradually bring the book nearer the eye; at a certain distance the circle disappears because its image falls upon the entrance of the optic nerve. Bring the book still nearer; the circle reappears.

57. *Field of Acute Vision.* — Look at a printed page without moving the eyes and observe how few words can be seen distinctly. The diameter of this field of distinct view will probably be found to be about one and one-half inches. Wherever the image of an object falls outside the yellow spot, it is seen indistinctly.

58. *Binocular Vision.* — Hold before each eye a blackened tube of pasteboard. Two distinct fields will be seen on looking through the tubes. Cause the tubes to converge at their free ends, and the two fields will finally fuse into one. This position of the two tubes represents approximately the normal convergence of the two optical axes. Converge the tubes still more; the two fields reappear, but they are crossed. Look through the tubes at near and at far objects. It will be found that, in order to have a single field of vision, the tubes must be converged more for the near objects.

59. Close one eye, and, looking steadily ahead, note how much is comprised in the field of view. On opening the eye the field is considerably enlarged.

60. Holding the forefinger six or eight inches in front of the nose, look at a distant object, as a tree. The forefinger appears double. Now accommodate the eyes for the finger; the tree appears double. An explanation of this can be deduced from Ex. 58.

61. *Movements of the Eye.* — Close one eye, and, holding the finger tip on the lid, feel the movements of that eye as the other eye looks about in various directions.

62. *Duration of Sight Sensations.*— Cause a small wheel to revolve rapidly; the spokes no longer appear distinct, but seem to be thinned out and fused together into a semitransparent membrane. Spin a top composed of an angular piece of card fastened to a suitable axis. It appears circular instead of angular.

63. Look at a bright light for a moment. Then close the eyes; the image persists for a short time.

64. *Fatigue of the Retina. After Images.*— Look steadily, for one or two minutes, at a window, and then at a plain light-colored wall. An image in which the light parts of the window are dark and the dark parts are light will now be seen.

65. *Complementary Colors.*— Look steadily at a piece of red paper and then at a light background; a light green after image will be seen. Repeat, using different colored papers. From dealers in kindergarten supplies can be obtained packages of colored papers suitable for this and other experiments on color.

66. *Color Blindness.*— The teacher frequently finds pupils unable to name colors correctly. This may be due to color blindness, but in most cases is caused by defective training. To make any accurate tests of color blindness, the teacher should procure a set of Holmgren's test worsteds (price $2.50) and directions for experimenting.

CHAPTER IX

THE EAR AND THE SENSE OF HEARING

167. The ear is the mechanism by which we hear. has three main divisions, called the *external*, the *midd* and the *internal ear* (Fig. 74).

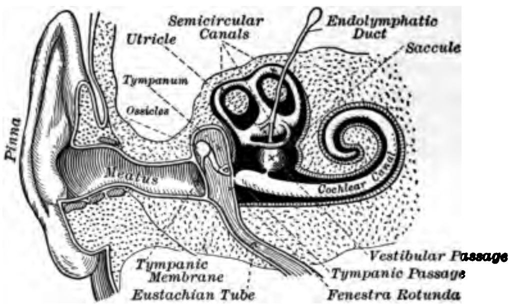


Fig. 74. — **Diagram of the ear, showing relationship of its parts.**

168. The External Ear. — The parts of the external e are formed to collect and conduct waves of sound to t inner portions of the auditory apparatus. They are t *pinna*, the *external meatus*, and the *membrane of the tymp num*. The pinna is a sheet of elastic cartilage cover with skin, so folded as to direct the waves of sou through the cartilaginous tube of the meatus, which continuous with it, to the membrane of the tympanum, *eardrum*, which closes the end of the passage. Alo

the tube of the meatus are placed the *wax glands* with their ducts.

169. The Middle Ear, or Tympanum, is an irregular cavity in the temporal bone, lined with mucous membrane which is supplied with small glands. By means of the *Eustachian tube*, which passes from the lower back part to the pharynx, or upper cavity of the throat, the tympanum communicates with the external air, and so equalizes the pressure upon the two sides of the membrane of the tympanum which separates the middle from the external ear.

Opposite the membrane of the tympanum are two smaller openings into the chamber of the inner ear, called the *round window* (*fenestra rotunda*), and the *oval window* (*fenestra ovalis*). These are closed, however, by thin membranes. Three small bones, called the *auditory ossicles*, form a chain across the middle ear (Figs. 74 and 75). The *malleus*, or hammer, is attached by one end to the membrane of the tympanum, while the other end articulates with the *incus*, or anvil bone. The incus articulates with the third bone, the *stapes*, or stirrup bone, at the top of its arch. The foot plate of the stapes fits into the opening on the inner side of the tympanum called the oval window, and is attached to the membrane which closes it.

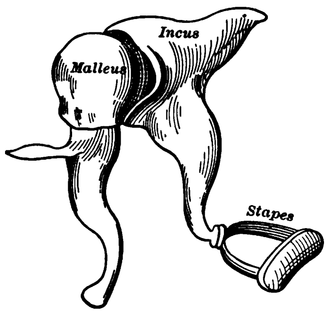


Fig. 75.—The ossicles of the ear.

170. The Internal Ear, or Labyrinth, is the essential part of the organ of hearing, the others being merely conductors of sound waves. The *labyrinth* is an irregular chamber in the rocky part of the temporal bone (Figs. 74

and 76). Within it lies a closed membranous sac called the *membranous labyrinth*, which follows the windings of the bony cavity, and whose parts receive names corresponding to the names given to the parts of the cavity.

The central part of the labyrinth is called the ***vestibule;*** it is about one eighth of an inch in diameter. In its walls are the round and oval windows already mentioned. The ***membranous vestibule*** is composed of two bags, called the ***utricle*** and the ***saccule***, connected by a roundabout passage.

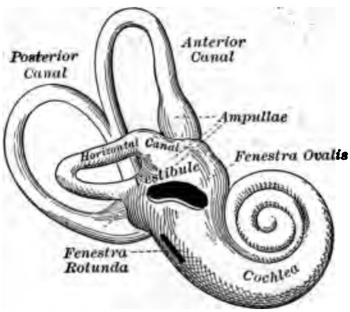


Fig. 76. — The bony labyrinth of the right ear.

171. From the utricle arise three ***semicircular canals***, lying in the bony passages of the same name. One of these is horizontal when a person stands upright; the others are vertical but at right angles to each other. Two of these canals are united at one end, so that there are but five openings from the canals into the vestibule. Each canal has a swelling at one end called the *ampulla*. At those swellings fibers from the eighth cranial (auditory) nerve pass from the bony wall through the membranes of the canals, firmly attaching one to the other. For the rest of their course the membranous tubes are free, or only loosely fastened by bands of connective tissue to the bony walls.

172. The Cochlea is the third and most complex division of the inner ear. It has much the appearance of a snail shell of two and a half coils. A bony tube is coiled spirally round a central tapering pillar of bone. Into this tube

projects from the central pillar a thin shelf of bone partly dividing the tube into two parts.

173. The Membranous Cochlea. — From the edge of the bony shelf of the cochlea two membranes reach to the opposite wall of the cochlea and divide the cavity into three spiral tubes (Fig. 77). One of these, the vestibular

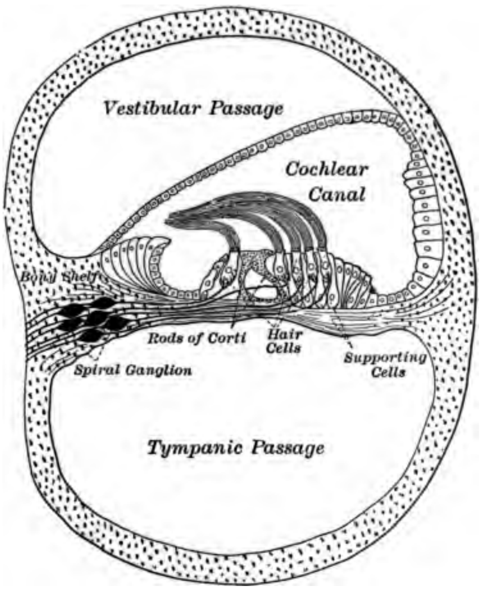


Fig. 77.— Diagram of a cross section of a single coil of the cochlea.
Showing the structures that compose the organ of Corti.

passage (*scala vestibuli*), communicates with the vestibule. A second, the tympanic passage (*scala tympani*), has its base against the membrane of the round window. At the apex of the coil of the cochlea the vestibular and tympanic passages communicate with each other (Fig. 74). The middle passage, the *membranous cochlea*, or cochlear

canal, is closed at its apex, but opens near its base into the saccule. In the cochlear canal is situated the most delicate part of the ear, the *organ of Corti.*

174. Fluids of the Labyrinth. — The bony canal of the inner ear is lined with a fine membrane which secretes a thin fluid, filling all the spaces of the chamber. The closed sac of the membranous labyrinth also secretes a fluid similar in composition, but containing less solid matter. When the membrane of the tympanum is thrown into vibration, the movement is communicated to the fluid filling the bony labyrinth, and then through the thin wall of the membranous labyrinth to the fluid inclosed, and so to the terminations of the auditory nerve.

175. The Auditory Nerve and the End Organs for Hearing. — The eighth cranial nerve arises by two roots in certain nerve centers of the medulla oblongata. Its two divisions enter the labyrinth between the base of the cochlea and the vestibule. One division, having several branches, goes to the vestibule and semicircular canals; the other passes up through a channel in the bony axis of the cochlea, giving forth fibers on its way to the bony shelf described above. These pass through, or come into relation with the *spiral ganglion* and reach the *organ of Corti.*

176. The Organ of Corti (Fig. 77), within the membranous cochlea, is understood to contain the end organs for the discrimination of degrees, variations, and qualities of sound. It is composed of the *rods of Corti* with adjacent hair cells and supporting parts. The rods are pillar-like cells attached by an expanded foot, or base, to one of the membranes of the cochlea and ending in a swelling called the head.

The pillars are arranged in pairs, of which there are from three thousand to five thousand, separated at their

bases but leaning toward each other to form an arched roof or tunnel. Toward the apex of the cochlea the rods increase in length but are more widely separated at the base, so that the tunnel becomes lower and wider. Against the rods lean other cells called *hair cells*, which end in many long, hairlike processes. Between the hair cells lie certain elongated supporting cells. The nerve fibers end in fine branches between and around the hair cells.

177. **Path of an Auditory Impression.** — Sound waves pass through the air and fall upon the membrane of the tympanum. In the middle ear they travel partly through air and partly through solid bodies — membranes and bones, — and in the inner ear through fluids and membranes. Vibrations of the membrane of the tympanum are "damped" by the ossicles of the middle ear, which also receive and pass on the auditory tremors to the membrane closing the oval window. These bones are so closely bound together that they vibrate as if they were one, the very slight amount of play at the articulations serving to prevent jar and fracture.

From the middle ear vibrations pass to the inner ear through the attachment of the stapes to the membrane of the oval window. Movement of that membrane sets up motion in the fluid filling the cavity. That, however, would not be possible (since the fluid is inelastic and incompressible) were not a vent provided at the round window. When the stapes pushes in the membrane of the oval window, that of the round window bulges outward, and the action agitates the whole body of the fluid which fills the bony labyrinth. But the vibrations in the fluid are also communicated to the walls of the membranous labyrinth which it bathes, and the fluid which the latter contains is thereby set in motion.

Within the swollen ends of the semicircular canals, and upon the walls of the utricle and the saccule, are projecting ridges composed of especially modified cells of the lining, between which are spindle-shaped *auditory cells* from which project *auditory hairs* into the fluid. Attached to these thickened disks, or ridges, are minute hard particles, called *otoliths*, which serve to increase the effect of the vibrations. The auditory vibrations in the fluid and in the membranous walls of the labyrinth reach the auditory hairs and give, according to the opinions of some authors, the sensation of sound, or mere noise. A branch of the vestibular division of the auditory nerve is distributed to the semicircular canals, and when its ends are affected by the vibrations in the fluids of the labyrinth there result, as is now believed, sensations other than perception of sound.

178. The same vibrations pass at the same time up the channel of the cochlea from below, affecting on their way the walls of the membranous cochlea, and throwing into vibration the fluid which they inclose. By the vibrations of the fluid and the membrane the nerve endings in the organ of Corti are acted upon in such a way as to give rise to auditory impulses, resulting in perception of sound quality—musical notes, harmony, etc. The cochlea alone is now regarded as concerned with hearing, other parts of the inner ear with equilibrium, etc. Sound waves may also reach the auditory cells by transmission through the bones of the head, as when one hears the ticking of a watch held between the teeth.

The auditory stimulus passes from the auditory cells by the minute nerve fibers to that branch of the eighth cranial, or auditory nerve, which passes through the cochlea and into the medulla oblongata (Fig. 78), whence

certain fibers have been traced to the corpora quadrigemina, while others convey the impression to the gray matter of certain convolutions of the temporal lobe of the cerebrum.

179. Function of the Vestibule and Semicircular Canals. — Much research has in recent years been directed to the part played by these portions of the inner ear, but no investigator has yet reached a conclusion which is accepted in all its details by all others. It is, however, generally believed that these parts have little, if any, direct concern with the sense of hearing and discriminating sounds. The nerve branches distributed here arise in the brain from a root of the auditory nerve different from that which sends nerves to the cochlea. The cerebellum, from which some of its fibers come, is well known to be the great center for coördination of muscular movement, and experiments seem to indicate that what is called the vestibular branch of the auditory nerve, which ends in the vestibule and semicircular canals, conveys to the brain impressions of position and of movement in space which have to do with the sense of equilibrium.

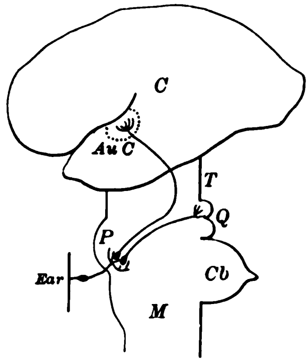


Fig. 78. — Diagram of the path of an auditory impulse.

The impulse passes from the auditory cells in the ear to the center of hearing (*Au C*) in the temporal lobe of the cerebrum. Some fibers pass to the anterior corpora quadrigemina (*Q*).

180. Hearing with Two Ears. — The two organs and two nerves of hearing convey to the brain, not two sensations, but one. By means of two ears we are able to some extent to determine the locality from which sounds come,

but our judgment as to position in space of sound-producing bodies, and of directions of sound, are indirect and not always reliable.

181. Differences in Sound Perception. — The ears of different persons vary greatly in power to distinguish differences in sound and in pitch, or the number of vibrations in a given time. All are limited in the perception of high-pitched notes. The ear may become wearied in respect to sound of a particular pitch, much as the eye is soon fatigued in respect to a particular color.

182. Care of the Ear. — A cold which causes inflammation of the throat often affects the lining membrane of the Eustachian tube and that of the middle ear, causing temporary partial deafness. If the cause often recurs, one or both ears may be permanently impaired. Sometimes repeated attacks of inflammation in the ear — as from abscesses — result in perforation of the membrane of the tympanum and great injury to the hearing.

Generally the wax which is secreted in the external canal of the ear needs no attention, and should not be picked out. Occasionally, however, it accumulates and hardens upon the membrane of the tympanum so as to interfere with its vibrations and impair the hearing. In such a case it should be removed by a surgeon.

Warm or tepid water should be used for washing the ears — never very cold water. Before going to baths in cold water or in salt water the ears should be filled with soft absorbent cotton.

A sudden very loud noise, as from a gun or cannon, has been known to rupture the eardrum, and a sudden shout close to a child's ear has been known to make it deaf. Insects sometimes crawl into the canal of the ear, in spite of the wax and the hairs there which usually

prevent such accidents. They do not often do harm, and may be removed by dropping warm water into the ear.

Demonstrations and Experiments

67. *Dissection of the Ear.* — The external and the middle ear can be very easily studied by making a dissection of the head of a cat or other domestic animal. Remove the lower jaw, expose and open the temporal bulla. The latter is in many animals a conspicuous rounded protuberance near the articulation of the jaw. The tympanic cavity with the contained ossicles, etc., can then be studied. The internal ear cannot be easily examined because of its smallness and well-nigh inaccessible situation in the rocky portion of the temporal bone. The bone which contains it can be dissected out, and the general outlines of the cochlear region discerned. Or, this portion of the skull may be treated with weak solution of muriatic acid for some days, after which the parts may be partly dissected out.

68. *Effect of Varying Air Tension in the Tympanum.* — While listening to a ticking watch, close both nose and mouth, and expel as much air as possible from the lungs, thus forcing the air through the Eustachian tube into the middle ear. The ticking sounds fainter. Or under like conditions inhale as much as possible. The result is as before.

69. *Judgment of the Direction of Sounds.* — Let a pupil, seated, keep his eyes closed. Clink together two coins at varying distances and directions from his head, and require him to indicate the direction of the sound. Observe that while he rarely fails to distinguish between right and left, he often errs in respect to other directions. Have him hold his hands vertically one in front of each ear, and see if his judgment of direction is thereby altered. Close one of his ears with absorbent cotton, and try the effect upon his location of sounds.

70. *Auditory Fatigue.* — Strike a tuning fork, press the stem down upon the crown of the head, and hold it there until the sound dies away. Then remove it, and after a short interval replace it. The sound will be heard again, but very faintly.

CHAPTER X

THE VOCAL APPARATUS

183. The Larynx, which contains the *vocal cords*, is the special voice organ. It is a chamber made up of cartilages, membranes, and muscles. Four cartilages compose the framework. The *thyroid* is the largest, and forms a prominent ridge in front (called "Adam's apple") with broad, flat sheets at the sides, ending in prolonged angles, above and below (Figs. 79 and 80). It does not meet at the back of the larynx. The *cricoid cartilage*, on the other hand, is a complete ring, the back being much wider than the front. On top of the broad hinder portion of the cricoid are the small, triangular *arytenoid cartilages*, which form with the cricoid a true joint, having synovial membrane and ligaments (Fig. 81).

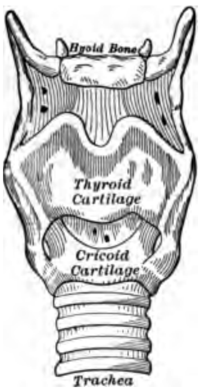


Fig. 79. — Front (ventral) view of larynx.

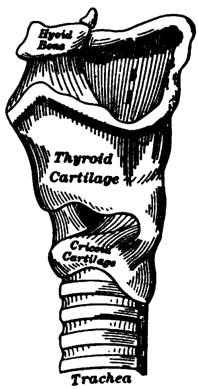


Fig. 80. — Side view of larynx.

Besides these four principal cartilages, which are of hyaline, or nonfibrous cartilage, there are five others of

yellow fibrocartilage. They are the *epiglottis*, which is attached to the upper front part of the larynx and forms a lid to the chamber; the *cartilages of Santorini*, little horn-shaped projections perched on top of the arytenoids; and the *cartilages of Weisberg*, which are still smaller bits of cartilage lying in folds of the mucous membrane in the sides of the upper membranous lining of the larynx.

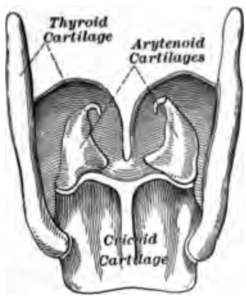


Fig. 81. — Cartilages of larynx, back (dorsal) view.

A sheet of membrane connects the thyroid cartilage with the hyoid bone at the root of the tongue (Figs. 79 and 80). The thyroid is also joined to the cricoid by joints with synovial membrane, and the lower projections, or horns, of the thyroid clasp the cricoid closely, though permitting movement between them. The cricoid is attached by membrane to the upper cartilaginous ring of the trachea, or windpipe. These parts, with the many small muscles and ligaments attached, form the vocal apparatus.

184. The larynx is flattened behind, where it closely adheres to the esophagus (Fig. 82). The *esophagus* is the muscular tube which conveys food and drink from the mouth to the stomach. Its enlarged upper portion is called the *pharynx*, and lies back of the cavity of the mouth. The larynx lies below and in front of the pharynx. In ordinary respiration the epiglottis stands nearly erect, leaving open the *glottis*, or passage into the larynx. In the process of swallowing, the epiglottis is pressed backward and downward, closing the glottis and permitting the food to slide down the esophagus instead of dropping into the windpipe.

185. The Vocal Cords. — The larynx is smoothly line with mucous membrane except where it narrows at th glottis. Here at the base of the epiglottis are seen, firs on each side of the lining membrane, ridges called *fal vocal cords*, which are not concerned in speech (Fig. 82 They play the chief part in closure of the glottis durin expiration. A little below them are the *true vocal cord*

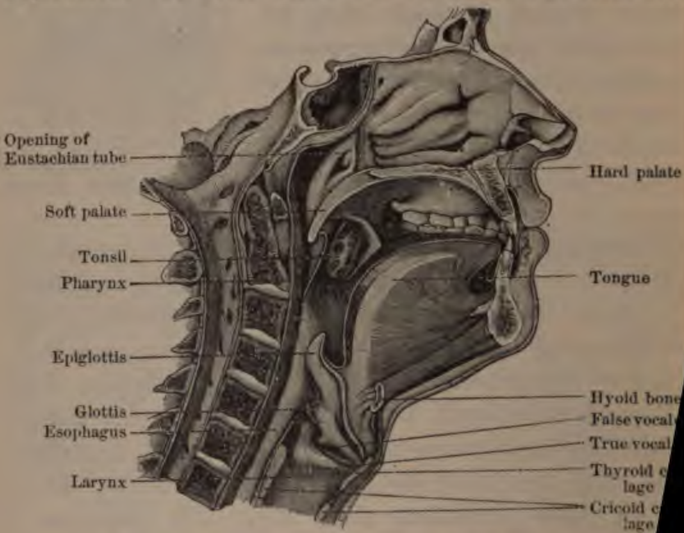


Fig. 82. — Vertical section of the head and neck.

thickened bands of elastic tissue running in the m membrane from the front angle of the thyroid ca backward to their attachment at the base of the ar cartilages. Between the true and the false vocal cor each side, a recess called the *ventricle*. The true vo have fine, smooth edges, and are shining white in

186. The Glottis. — In ordinary respiration the a triangular opening with its apex in front. I

labored breathing it widens during inspiration and narrows during expiration.

187. Vocalization. — There may be a sort of speech without the action of the larynx or the vocal cords, when the muscles of respiration, the lips, and what are called the *resonating cavities* above the larynx are alone brought into play. This produces *whispering*. But for vocalization the vocal cords must be brought very near together, made tense and parallel, and a current of air must be forced swiftly through the narrow slit, throwing them into rapid vibration. This is effected by means of a complicated arrangement of muscles and ligaments attached to the various cartilages. The two inner angles of the arytenoid cartilages are drawn together by the contraction of certain muscles, while others contract to stretch the vocal cords. The thyroid and cricoid cartilages move upon each other to assist in the process. The muscles of the thorax and the abdomen are also brought into special action, and the column of air in the air chamber composed of the trachea and the bronchial system is thrown into vibration. Sound is a result of the whole process.

188. The Resonating Cavities (Fig. 82). — The pharynx, the mouth, and the nasal chambers are *resonating cavities*, which, by very slight changes in form and size, are able to bring into special prominence different parts of the general tone produced in the larynx, and so modify the resulting sound.

189. Speech is the enunciation of articulate sounds to express thought, and is the result of the action of the voluntary muscles by which the vibrations produced in the larynx are modified in the resonating cavities. The faculty of speech is a distinctive gift of man, and is possessed by no other animal. It is a natural gift, but its use is the

result of training, and skill is acquired only by long years of practice. The complex and greatly varied action required in speech may take place with great rapidity, and may be continued for hours without exhaustion, as in the case of an accomplished singer or public speaker.

190. Vowels and Consonants. — Voice becomes speech through the modifying action of the lips, tongue, throat, etc. Those sounds of the spoken alphabet which require the more open mouth, the more resonant and more prolonged tone, are called *vowels;* those which are uttered with the closer position, and are less prolonged and less resonant, are called *consonants.* Compare the position of the parts of the mouth in enunciating the *a* in *far* with that in sounding the *b* in *cab*, for example. Between vowels and consonants there is no absolute division. Sounds represented by some of the letters are more open in some words or syllables than in others. Thus, *l* and *n* are sometimes vowels and sometimes consonants.

191. Quality of Voice. — Voices are spoken of as "soft," "harsh," "rasping," "rough," "sweet," "low," "gentle," etc. An agreeable voice is a most attractive characteristic and a most desirable possession. As the vocal apparatus is wholly under the control of the will, and as its use is chiefly a matter of imitation, it is of great importance that while the habit of speech is forming the young should be associated with those whose vocal habits are agreeable and refined, and that the attention of children should be early directed to the cultivation of soft and pleasant tones of voice. In this respect Americans are especially negligent, and "the American voice" has become a byword and a reproach in Europe.

192. Musical Sounds.—Sounds produced by regular vibrations are *musical.* Irregular vibrations result in *noise.*

No sharp line of separation can, however, be drawn. The sounds of ordinary speech are due to regular vibrations, and are hence musical.

193. Pitch depends upon the rapidity of the vibrations, and that varies with the length of the cords and with their tension. In women the vocal cords are shorter than in men, and the voice is an octave higher in pitch. Pitch due to tension of the cords is a matter of voluntary control within the range of a voice. *Loudness* depends upon the force of expiration. *Stammering* is due to lack of coördination in the muscles of speech.

194. Nervous Mechanism of the Larynx. — A certain area in the left hemisphere of the cerebrum is recognized as the nervous center in which impulses resulting in speech originate. From the cells of this center nerve fibers run to other cells in the wall of the fourth ventricle of the brain, to the medulla oblongata, and on into the spinal cord. By means of these communicating fibers the center for speech is brought into connection with other groups of nerve cells, from which arise the various nerves which are concerned in vocalization. These are very numerous, for the muscles of the face, the tongue, the thorax, and the abdomen, as well as those of the larynx, are called into action in speaking, singing, etc. Those nerves distributed to the muscles of the larynx are branches of the *vagus*, or *pneumogastric*, which is the tenth cranial nerve and rises from the medulla oblongata.

Suppose there arises in a man's mind a thought which he desires to express in audible speech. He remembers the sounds of the words which will serve his purpose, and impulses arise in that part of the speech center called the *auditory word center*, from which they pass to the *motor center*. Thence the nerves of the various parts of the

vocal apparatus distribute the impulse to the necessary muscles. In reading aloud it is the end organs for vision, the eyes, which are first stimulated (Fig. 83); then the impulse is carried to the visual center in the brain, from which nervous influences travel by connecting nerve fibers to the auditory word center. There, as before, the sound of the words is revived and the impulse follows the path previously described.

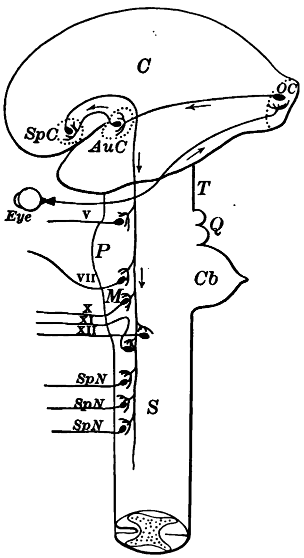


Fig. 83. — Diagram of path of nervous impulses in reading aloud.

Au C hearing center.
OC sight center.
Sp C speech center in left hemisphere.
V, VII, X, XI, XII, *Sp N* nerves supplying motor fibers to the speech organs: lips, tongue, chest, etc.

195. — When a person writes from dictation, another course is followed (Fig. 84). The auditory end organs of the inner ear are first stimulated; the impression travels by the auditory nerves to the auditory word center, then across to the visual word center, reviving there the appearance of the words. Impulses pass thence to the motor centers and by motor nerves to the various muscles of the arm and hand involved in writing. If nerve fibers which connect the two word centers, visual and auditory, are diseased, neither reading aloud nor writing from dictation is possible.

Vocalization may also be the result of reflex nervous action, as when an involuntary scream follows sudden *fright.*

196. Dumbness is most frequently due to deafness. The auditory word center has never been stimulated. In recent years it has been found possible to stimulate the speech center through its connection with the visual center. Children born deaf are taught to imitate the movements of the mouth, tongue, and throat of one who speaks, and speech results from these remembered movements acting upon the speech center.

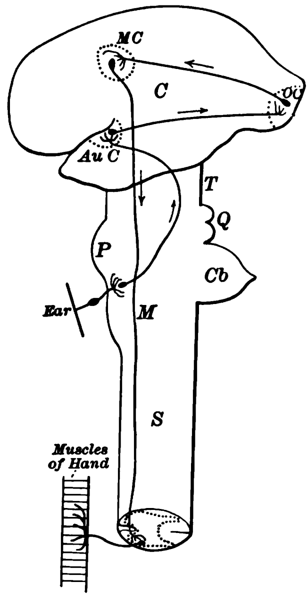


Fig. 84.—Diagram of the path of the nervous impulses in writing from dictation.

Au C center of hearing.
MC motor center.
OC sight center.

197. Care of Throat and Voice.—If the delicate lining membrane of the larynx becomes inflamed through "taking cold" or from exposure to dust or irritating gases or from overuse or strain of the vocal cords, the voice is injured and its use may become painful or impossible. These causes should be avoided. When a daily cold bath is not practicable, a dash of cold water over the neck on rising in the morning will prove a tonic for the throat and help to avert colds, hoarseness, and sore throat. *Breathing* should be through the nose, and not through the mouth, and children should be trained in infancy to sleep with the mouth closed. In going from the warm air of the house into the cold outer air in winter the precaution of closing the mouth is especially to be observed. Pass-

ing through the winding nasal canal, the air becomes tempered before reaching the sensitive membranes of throat and lungs; also much of the dust always present in the atmosphere is caught by the moist mucous lining of the nostrils, and the deeper air passages are protected.

It is not necessary, in order to avoid cold, that the throat should be thickly swathed in wraps of wool and fur. Too much clothing about the neck causes excess of perspiration there and makes the parts weak and tender.

198. Special Training of the voice for singing or public speaking should not be begun by either boys or girls before the age of sixteen or seventeen, and should always be attended with judgment and care against overstrain.

199. Alcohol and Tobacco as affecting the Vocal Organs. — As the perfect control of the voice depends upon the healthy condition of all the muscles connected with the vocal apparatus, and upon the accurate adjustment of nervous force to their varying needs, anything which affects those muscles or the nerves affects also the voice. *Alcohol* and *tobacco* do affect both. The mucous membrane of the larynx is often much inflamed by tobacco smoking, and especially by the use of cigarettes. The inflammation may extend through the Eustachian tubes, impairing the hearing, and into the bronchial tubes, causing an annoying cough. A disease known as "smoker's sore throat" may result. Alcoholic beverages irritate the throat and are often forbidden to those cultivating the voice for singing.

Demonstration

71. *Dissection of the Larynx.* — At a slaughterhouse can be obtained a trachea of an ox with the larynx intact and a portion of the esophagus; the hyoid bone may be present also. With this material the *principal* topics of this chapter can be illustrated.

PART III

NERVOUS OPERATIONS UNCONNECTED WITH CONSCIOUSNESS

Those nervous operations of which man is necessarily conscious and which are directly concerned in his usefulness and happiness, cannot continue to minister to his higher nature without the assistance of another set of actions of which he is in health almost wholly unconscious. The complicated mechanisms for producing sensation and voluntary motion are constantly worn away at every point, and every tissue must be as constantly renewed. Through the action, at every moment of life, of nerves and nerve cells whose office it is to preside over what are called the vital processes, the body is kept in condition for the exercise of its conscious powers. Those vital processes are included under the general term *nutrition*, that is, the growth, waste, and repair of tissue. Nutrition is effected by means of the *circulation of the blood*, *digestion* (including *absorption* and *assimilation*), *respiration*, and *excretion*. Because these operations are wholly dependent upon nervous influences, and because they go on through life without necessary connection with consciousness, they are grouped here as unconscious nervous operations.

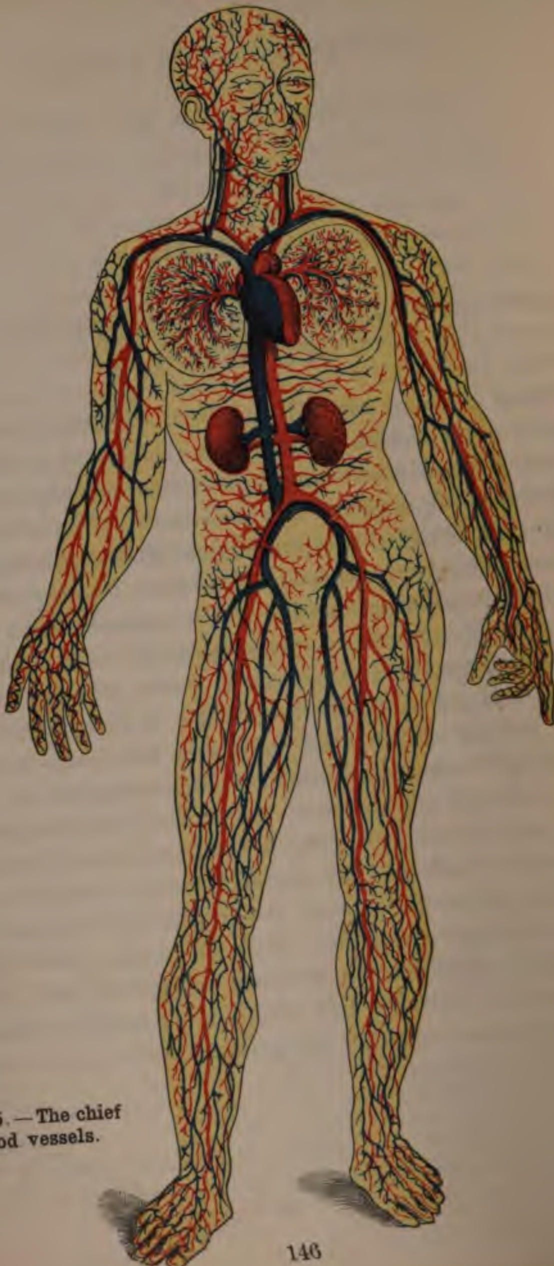


Fig. 85. — The chief blood vessels.

CHAPTER XI

BLOOD, LYMPH, AND CHYLE

200. Function of the Blood. — It will be remembered that one of the essential properties of the living cell is its power to incorporate into its own substance matter from outside itself, a process which results in growth or in repairing waste; while another property, involved in this, is the power to break down by oxidation, that is, to resolve portions of its own body into simpler chemical substances, thus producing waste matter.

In order that this double process may go on continually (as it must while the cell is living), oxygen and oxidizable substances, that is, food, must be brought to each cell, and provision must be made for removing the waste products. The blood is the medium for accomplishing this.

201. The Blood as a Tissue. — Blood is classed, for valid reasons, among the connective tissues. While it does not furnish support to the body or its parts in the same sense as do more solid connective tissues, — such as bone or cartilage, — it does support the whole body by conveying nutriment to every part. It is like other connective tissues also in that the cells make up a comparatively small portion of its substance, the intercellular material being largely in excess. And, finally, it is formed in the development of the embryo from the same layer as are the other connective tissues.

202. Structure of the Blood. — Under the microscope the blood is seen to consist of a nearly colorless fluid, the *plasma*, in which float cells of two sorts, called from their color the *red* and the *white* (or colorless) *corpuscles* (Fig. 17, p. 26). Ordinarily there are several hundreds of red corpuscles to one of the white corpuscles, and to them the color of the blood is due.

203. The Quantity of Blood in the human body is estimated at about one thirteenth the body's total weight, or, in a person of average size, about one and a quarter gallons. Any deficiency of blood in the body (as from hemorrhage), is soon supplied by the passage of water from the tissues to the blood by means of the lymph (§ 209), and an excess is removed by the transfer of water to the tissues, and by the secretion of the kidneys. Thus the quantity of blood in the system is practically invariable.

204. The Red Corpuscles are unnucleated cells, all of nearly the same size — about $\frac{1}{3200}$ of an inch in diameter, and one fourth of that in thickness. They are round and flat, but slightly thicker at the edge than in the middle. Being flexible and elastic they are bent out of shape as they are crowded together in the current, but resume their usual form when the pressure is removed. They have a close, colorless, spongy framework, — the *stroma*, — while by far the larger part of their substance is a red coloring matter in the meshes of the stroma, called *hemoglobin*. This is the useful part of the corpuscle, the stroma apparently having only the office of holding the hemoglobin in convenient shape.

205. The Formation of the Red Corpuscles is found to take place in the *red marrow* of the bones. The peculiar tissue called red marrow is richly supplied with blood vessels

having very thin walls. Within these vessels are found colored nucleated cells, some of which become changed in the marrow into unnucleated red disks which are swept into the blood current. It is the important function of the red corpuscles to take in oxygen from the air which reaches the blood in the lungs, and carry it to the other tissues of the body. The red corpuscle lives in the blood for an unknown time. When it dies, a new one takes its place. The spleen also is believed to aid in the manufacture of both the red corpuscles and the white, but we have little positive knowledge upon the subject.

206. The White Corpuscles are mostly larger than the red, being generally about $\frac{1}{2500}$ of an inch in diameter, though some are smaller than the red. Some are globular masses of granular protoplasm without cell walls and having one or more nuclei. Others are of irregular and constantly changing shape, less granular than the first and with several nuclei. Many writers have remarked the striking likeness of these corpuscles to the one-celled animalcule, the amœba. They have the same power as the amœba to change their shape spontaneously, sending out processes from various parts of their circumference; and they are able to take in and digest the bacilli which are sometimes found in the blood, as the amœba digests food. There are found in the blood some other small bodies, whose nature and purpose are unknown.

207. Chemical Composition of Blood. — The blood is alkaline, owing to the presence of small quantities of alkaline salts. It contains chlorides, phosphates, and carbonates of sodium and potassium, and smaller quantities of calcium and magnesium.

208. Clotting of the Blood. — The blood in the blood vessels is perfectly fluid, but if drawn out and allowed to

stand for a few minutes, it becomes a firm mass of jelly. After an hour or more, a yellow fluid, called *serum*, begins to ooze from the clot, which shrinks in size. The clotting is caused by the formation, in the liquid blood, of a close network of fine fibrils, called *fibrin*, in which the corpuscles of both kinds are entangled, while serum is the plasma of the blood, minus an element in its composition called *fibrinogen*, which changes into the solid fibrin in the coagulation. It is thought that when the blood leaves the blood vessel, or in some way comes in contact with foreign matter, a portion of the white corpuscles are broken up, and thus is set free a peculiar substance called *fibrin ferment*. It is this which acts upon the fibrinogen, and causes it to become fibrin. The fibrin may be gotten out from a quantity of freshly drawn blood by quickly stirring or whipping it with a bunch of twigs. The tiny white threads cling to the sticks, and by washing in water may be freed from the few entangled corpuscles which remain, leaving the fibrin pure.

This power which the blood has to clot is of great value, since by its means small breakages in or injuries to the innumerable tubes conveying the blood throughout the system are quickly stopped, and the serious hemorrhage which would otherwise result is quickly checked, while the ruptured wall of the blood vessel is given time to heal.

209. Lymph. — It is by the blood that nutriment is carried to every part of the body; but the blood is always inclosed within the walls of the tubes called blood vessels, and, as blood, does not come in contact with the cells of the tissues.

In the capillaries, which are the finest ramifications of the blood vessels, some of the plasma passes from the

blood through the walls of the vessels into the spaces between those walls and the substance of the tissues around. This fluid is called *lymph*, and is that which nourishes the tissue elements. It is clear, nearly transparent, and contains more water with less solid matter than the plasma of the blood. White corpuscles similar to those in the blood are found in it, and, like the blood, it coagulates by the formation of fibrin. Like the blood, also, lymph is conveyed from the tissues in tubes, the *lymphatics* or *lymphatic vessels*, which finally join the great blood vessels, and so return to the blood the substances drawn from it in the capillaries.

210. Lacteals and Chyle. — The lymphatics of the small intestine are called *lacteals;* after a meal containing fat, they convey, instead of clear lymph, a milky fluid which is called *chyle*, and is a product of digestion.

Experiments

72. *Blood Corpuscles.* — Prick the finger with a sterilized needle, mount the drop of blood thus obtained, and examine it with both low and high powers of the compound microscope. There will be seen large numbers of round bodies of a faint red tint — the red corpuscles. These are seen to be small disks, and appear dumb-bell shaped when viewed on edge, owing to their being thinner in the center than on the edges. Occasionally among the red corpuscles may be seen slightly larger, transparent, sometimes irregular, bodies — the white or colorless corpuscles. If watched for some time, they will probably show slight changes in shape.

73. *Clotting of Blood.* —At a slaughterhouse fresh blood can be obtained. If it be stirred vigorously immediately after being drawn from the blood vessels, the fibrin can be separated from the blood serum and corpuscles. Blood allowed to stand after being drawn shows a firm clot. Both "whipped" blood and fibrin and the clotted blood should be examined by the pupils.

The clotting of blood may be prevented by adding to it, as it is

drawn from the blood vessels, about one fourth its volume of a saturated solution of sulphate of magnesia. This "salted" blood may be kept in a cool place for several days without clotting. It may be made to clot by diluting it with five to ten times its volume of water.

A more satisfactory method of preventing the clotting of blood, the writer has found, consists in adding oxalate of potash in the proportion of one part of a 5 per cent solution of oxalate of potash to twenty-five parts of blood. The oxalate solution of the requisite amount should be placed in a vessel and the blood be allowed to flow into and mix with it. The mixing should be made thorough by vigorous shaking. To produce a clot, add a few drops of a 2 per cent solution of calcium chloride to some of the oxalate-blood. The potassium oxalate prevents clotting by precipitating the calcium salts necessary to coagulation. The addition of calcium chloride restores the calcium and renders clotting possible.

74. *The Minute Structure of the Fibrin Framework.* — To a drop of fresh blood on a slide add two drops of normal salt solution. Put on a cover glass and set aside an hour or so to clot. Add 50 per cent alcohol at the edge of the cover glass (to wash out the corpuscles and harden the fibrin). Observe with the microscope the network of fibrin fibrils. Care must be taken not to move the cover glass during the preparation for examination.

CHAPTER XII

THE CIRCULATORY SYSTEM

211. The apparatus distributing the blood throughout the body and keeping it constantly in motion is composed of the *heart*, the great central pump; *arteries*, tubes to carry blood from the heart; *veins*, which are tubes carrying blood to the heart; and *capillaries*, a network of small tubes connecting arteries and veins. These constitute the *vascular system* (Fig. 85, p. 146). In addition to them and forming a part of the complete circulatory system are the *lymphatics* and *lacteals*, sometimes called the *lymph vascular system*. They are tubes having walls thinner than those of the blood vessels, running from periphery to center, conveying *lymph* and *chyle*.

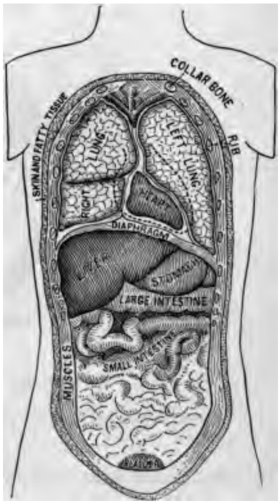


Fig. 86.—Front view of the viscera in their natural relations.
The heart is partly covered by the lungs, but its true outline is shown by a dotted line.

212. The Heart is a hollow, cone-shaped muscle, inclosed in a membranous sac called the *pericardium*, lying in the thorax between the right and left lungs (Fig. 86). Its base is directed backward and upward, while its

apex points downward and forward a little to the left of the sternum, or breastbone. The heart is divided longitudinally into two divisions wholly separate from each other. Each of these is divided again into two chambers which have free communication. The chambers at the base

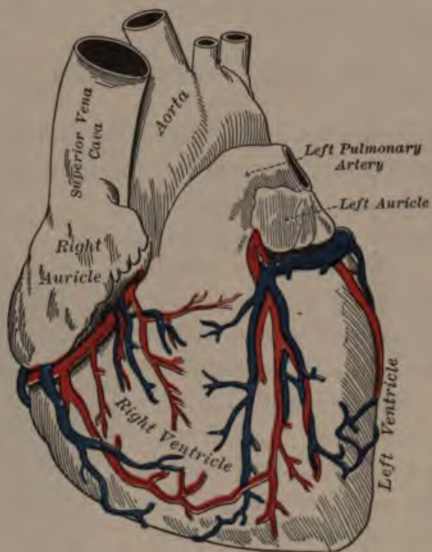


Fig. 87. — Front view of heart.

Coronary arteries and veins are injected, arteries red, veins blue.

of the cone are called the right and left *auricles*, while the other two are called right and left *ventricles* (Figs. 87 and 88). Lying upon the outside of the auricles are two flat earlike structures which are called the right and left *appendices*.

213. The Right Auricle lies on the right side of the upper part of the heart. Its walls are thin, and are pierced by openings for the two great veins, — the *superior vena cava*,

entering from above, and the *inferior vena cava*, entering from below. These two veins bring to the heart the blood from all parts of the body, except from the lungs and the heart itself. Close beside the inferior vena cava the *coronary vein* opens into the right auricle. This brings to

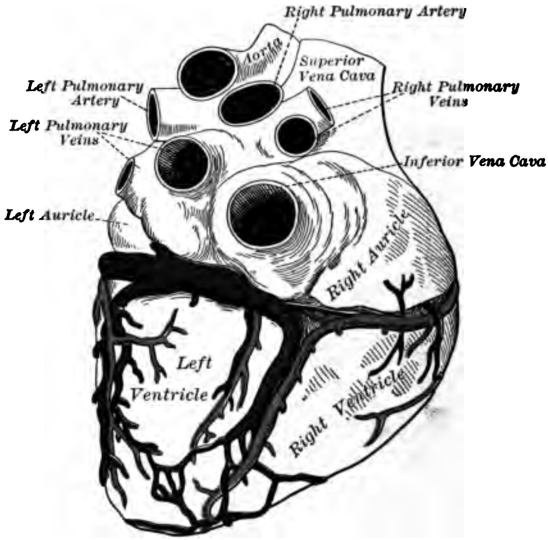


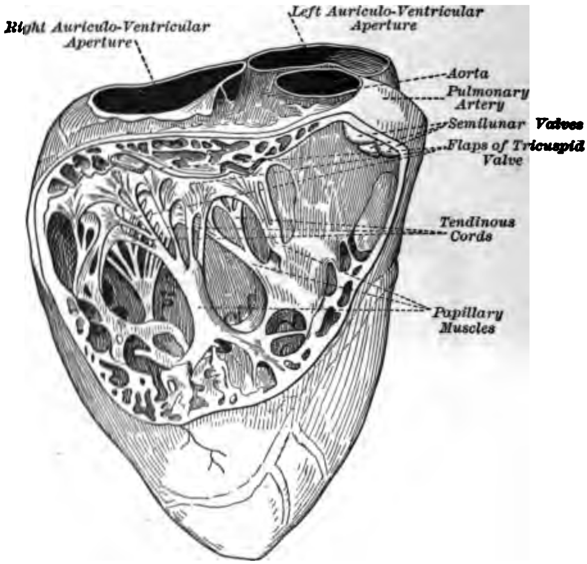
Fig. 88.—Heart seen from behind.

Coronary arteries and veins are injected, arteries red, veins blue.

the auricle the blood from the capillaries of the heart itself, which like all other organs of the body is supplied with blood vessels and lymphatics for its own nutrition.

214. The Left Auricle lies at the left and back of the upper part of the heart. Its walls are slightly thicker than those of the right auricle. It receives four *pulmonary veins*, two from each lung. The openings have no valves.

215. The Right Ventricle occupies the principal part of the forward surface of the heart, but is not a part of the apex. The walls are thicker than those of the auricles and less smooth. From the upper side of the cavity of the ventricle a large opening leads to the great *pulmonary artery*, while a still larger opening admits the blood from



89. Right ventricle, cut open to show the structures that regulate the action of the tricuspid valve.

the right auricle (Fig. 89). The *tricuspid* valves prevent the return of blood from the ventricle to the auricle. The three main divisions of the valve and three smaller ones are all triangular in shape, and are attached by their bases to a tendinous ring surrounding the opening. The thinner edges of the valves are flaps of transparent membrane

hanging downward and held by slender white *tendinous cords* attached to little projecting columns in the walls of the ventricle (*papillary muscles*). These cords and muscles keep the valves from being pressed back into the auricle further than is necessary to close the communication. Blood can thus flow from the auricle into the ventricle, but not from the ventricle to the auricle. The passage into the pulmonary artery is guarded by three folds, or pockets, in the lining membrane, called *semilunar valves*, which have their free edges turned upward, so that when the blood is forced upward into the artery, the valves lie flat against its walls, while if the blood should begin to flow backward, the little pockets would at once be filled, their edges crowded together in the center of the tube, and the opening closed.

216. The Left Ventricle occupies the chief part of the hinder surface of the heart, and includes the apex (Figs. 87 and 88). It opens at its upper side from the *left auricle* and into the *aorta*, the great artery whose branches bear the blood to the general system. The walls are much thicker than in any other part of the heart because greater force is required here to send the blood to the most distant parts of the body.

The *mitral* or *bicuspid valves* guard the opening into the left auricle. They are similar to the tricuspids, except that they have only two main divisions instead of three. Tendinous cords and papillary muscles hold their edges in place as in the case of the tricuspids. A strong fibrous ring surrounds the end of the *aorta*, and within its mouth are three *semilunar valves*, thicker and stronger than those of the pulmonary artery. Their action is like that of the other semilunar valves.

217. All the cavities of the heart are lined with a

smooth, shining membrane, the *endocardium*, which also covers the valves, and is continuous with the lining of the veins and arteries.

218. Cardiac Muscle. — As stated in the chapter on Muscles, the muscular fibers of the heart form a class by themselves, being *striped* but *involuntary* (Fig. 90). The fibers lie side by side, but send off at short intervals branches which unite them. The muscular fibers, moreover, are arranged in the wall of the heart in bundles in such a way that in contracting they draw the two sides of the walls of the chambers together until they meet. The muscle fibers of the walls of the auricles are distinct from those of the ventricles, so that they contract separately, as we shall see. Each fiber, or muscle cell, contains one nucleus.

Fig. 90.—Two cardiac muscle fibers.

Cardiac muscle fiber appears, to a large extent, to originate its own contraction, and is not so entirely as is a skeletal muscle fiber a mere instrument of a motor nerve fiber. The action of cardiac muscle under stimulus is not stronger or weaker in proportion to the strength of the stimulus, as is the case with skeletal muscles. A weak electric shock, if it causes any beat at all in the heart muscles, causes as strong a beat as does a strong stimulus.

219. Arteries are the vessels which convey the blood from the ventricles of the heart. The smallest of them have a few plain muscular fibers wrapped round the tube outside the endothelium. As the arteries grow larger, the number of muscle fibers increases till they form a definite muscular coat with a little connective tissue. In the largest arteries the walls consist of three layers (Fig. 91): (*a*) the inner coat, consisting of endothelium with a

thin elastic layer on its outer side; (*b*) a muscular and elastic coat; (*c*) a connective tissue coat, forming the outside of the vessel. The very largest arteries have more of the elastic in proportion to the muscular tissue. Owing to the presence of the elastic tissues, arteries may be stretched lengthwise, or distended by pressure from within, and will contract when the stretching force dis appears. Arteries have no valves; those at the beginning of the aorta and the pulmonary artery belong to the heart.

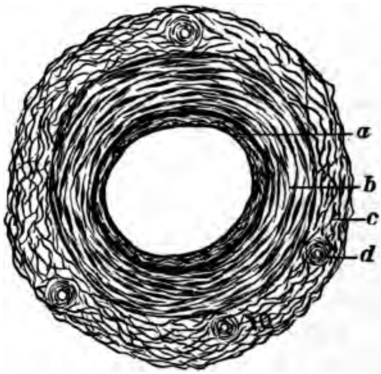


Fig. 91.—Cross section of an artery.
a smooth inner coat.
b middle or muscular coat.
c outer or connective tissue coat.
d small artery to nourish the large one.

Branches of the smaller arteries often run into one another, so that there is more than one path for the blood from point to point; if, by any means, one becomes closed, the blood can still pass round by another way.

220. Veins are the vessels which carry the blood toward the heart. Great arteries open from the ventricles. The great veins open into the auricles. Their walls are thinner than those of the arteries, and collapse when the veins are empty. They contain less of the elastic and muscular tissues than arteries. Veins are supplied with many semilunar valves, which prevent the blood from flowing in the wrong direction.

221. Vascular and Nervous Supply of Blood Vessels.—The coats of arteries and veins are supplied with their own arteries, capillaries, lymphatics, and veins by means of

which they are nourished; and nerve fibers from sympathetic nerves form plexuses around the blood vessels — plexuses from which nerve fibers penetrate between the muscle fibers of the muscular coat.

222. The Capillaries are the minute branches of veins and arteries which form a connection and means of communication between the two sets of vessels. Their walls are formed of an extremely thin membrane which is easily ruptured by unusual pressure. It is in the capillaries that occur all the changes which take place in the blood. In the web of a frog's foot, under the microscope, the movement of the blood in the capillaries may be seen.

223. Osmosis is the term applied to the phenomena of interchange between different fluids when in contact or when separated by membranes or walls having minute pores. By osmosis the blood inside the capillaries and the tissue elements on the outside become intermingled, and by the same means animal tissues live upon the lymph, which is in turn replenished by the blood, while certain elements pass from the protoplasmic cells of the tissues, by means of the lymph, into the blood. It is not true, however, that osmosis in living tissues is subject to the same laws as that which takes place through dead animal or vegetable membranes.

224. Course of the Blood in the Body. — In describing the circulation of the blood it is customary to speak of the *general* or *systemic circulation*, the *pulmonary circulation*, and the *portal circulation*. These are convenient terms, and are here retained for that reason. There is, however, but one circulation, by which the blood leaving any one part of the circulatory system returns to the same part again. To do so it must pass through two sets of capillaries and must be twice returned to the heart. The

blood of the portal circulation passes in the liver through a third set of capillaries.

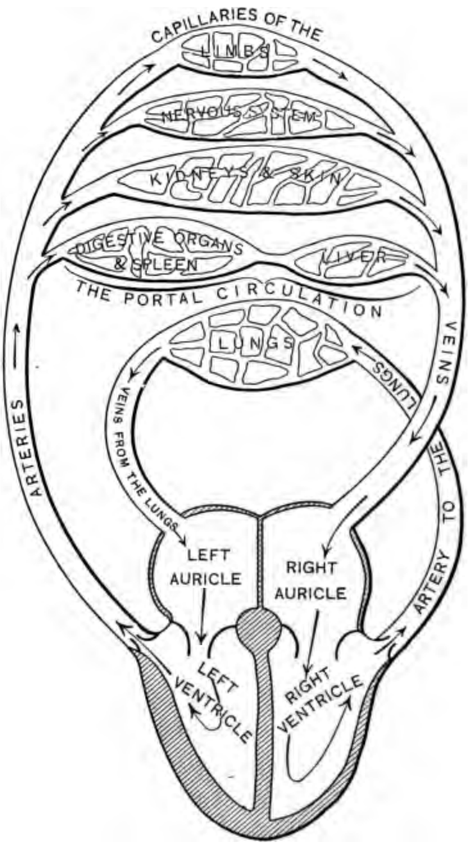


Fig. 92.—Diagram of the course of the blood in the circulation.

225. The General or Systemic Circulation (Figs. 85 and 92).—The blood leaves the heart by the *aorta*, which arises from the left ventricle and after forming a large

arch over the root of the left lung passes downward near the spinal column. Piercing the diaphragm, the aorta enters the abdomen, and at the fourth lumbar vertebra divides into the right and left *common iliac arteries*, and a third small branch (the *middle sacral*) which continues on to the end of the coccyx.

226. Branches of the Aorta (Figs. 85 and 93). — The first branches of the aorta are the two *coronary* arteries sent off just beyond the semilunar valves to supply the walls of the heart. The large branches from near the top of the arch are: (1) the *innominate* artery, which soon divides into two, the *right subclavian*, running to the right arm, and the *right carotid*, supplying the right side of the head and neck; (2) the *left common carotid* for the left side of the neck and head; and (3) the *left subclavian* artery for the left arm. Each subclavian artery gives off at the armpit the *axillary* and in the arm the *brachial* artery. The latter divides into the *ulnar* and the *radial* arteries, named from the bones along which they lie. They unite in the hand to form the *palmar arch.*

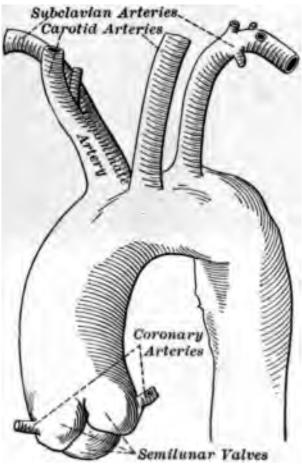


Fig. 93. — Arch of the aorta, dissected free from the rest of the heart.

The carotid arteries ascend the sides of the neck and divide into two branches, which supply the head and face and the brain.

The branches of the *aorta* within the thorax are (besides

the coronary) the two *bronchial*, which go to the lungs; the three or four *esophageal*, for the coats of the esophagus; the *pericardial*, for the pericardium; and numerous *intercostal* arteries.

Within the abdomen arise the *phrenic*, in the diaphragm; the *cœliac axis*, with three branches, — the *hepatic*, going mainly to the liver, the *gastric*, to the stomach, and the *splenic* to the spleen (Fig. 94); the *superior*

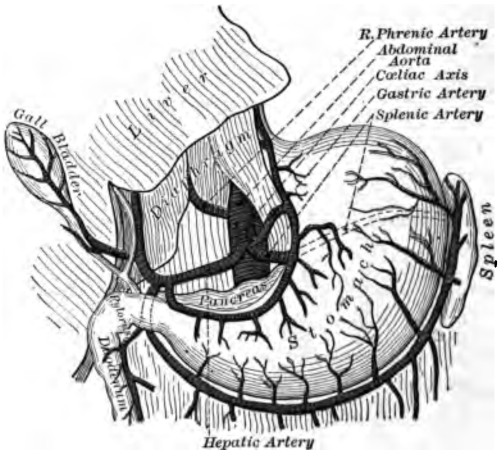


Fig. 94. — The cœliac axis and its branches.

and *inferior mesenteric*, which supply the intestine; and the *renal*, going to the kidneys.

The *iliac arteries* supply the walls and organs of the pelvis and the legs. The artery on the front and inner side of the thigh is called the *femoral;* above the knee joint it passes to the back side of the leg, and is there called the *popliteal*, while below the knee the main branches are the *tibial* and the *peroneal*, which unite in

the foot in a *palmar arch.* All these arteries give off numerous other branches all along their course.

227. The Principal Veins (Fig. 85). — The blood conveyed by the arteries to the capillaries of all parts of the body passes there into the small veins, which unite into larger ones, and, in general, run beside the arteries, and often have corresponding names. They are gathered into the *superior vena cava*, which collects the blood from the head, arms, and portions of the chest; the *inferior vena cava*, by which the blood is returned from the remainder of the body (the lungs and heart excepted) to the heart; and the *coronary vein* from the walls of the heart. All these veins empty their contents into the right auricle. Many of the veins are provided with valves to prevent the reflow of the blood.

228. The Pulmonary Circulation (Fig. 92). — From the right auricle the blood flows into the right ventricle, and by its contraction is forced into the *pulmonary artery*, which, dividing into two, one for each lung, carries the blood to the capillaries of the lungs. It is then collected by the *pulmonary veins* (two from each lung) and returned to the left auricle, and passes thence to the left ventricle, having completed the circuit of the body.

In the *systemic circulation* the arteries convey the pure, oxidized, nutrient blood to the capillaries, while the veins return the impure, deoxidized blood to the heart. In the *pulmonary circulation* the reverse is true. Impure blood flows through the pulmonary arteries to be oxidized in the lungs, and returned pure by the pulmonary veins.

229. The Portal Circulation is an accessory and peculiar circulation belonging to the liver. That organ not only receives arterial blood through the *hepatic artery*, but is *also supplied* by the *portal vein* with blood which has

already circulated through the capillaries of the stomach, spleen, intestines, and pancreas (Fig. 95). Unlike any other vein, the portal vein ends in a second set of capil-

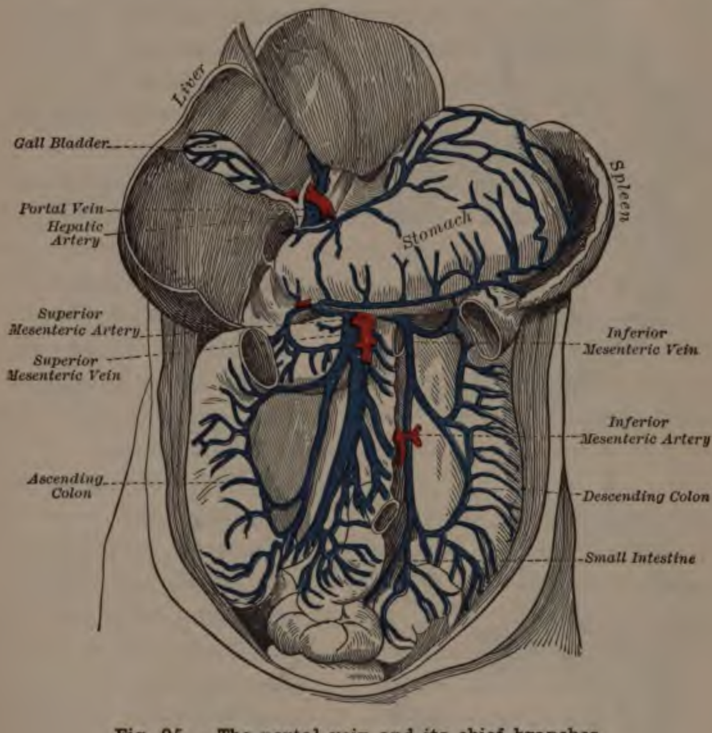


Fig. 95. — The portal vein and its chief branches.

The liver is turned back and the transverse colon and a part of the small intestine are cut away.

laries around the cells of the liver, from which it is collected into the *hepatic veins*, which open into the inferior vena cava.

230. Action of the Heart in the Circulation (Fig. 96). — In the *beating* of the heart, the contraction of the muscular walls commences at the mouths of the great veins in the auricles, runs through the two auricles and then over the two ventricles together, the auricles beginning to dilate as the ventricles begin to contract. Then there is an instant's *pause*, when neither set of muscles are contracting, but the whole heart is expanding, and its walls are soft and flabby.

The impulse from the heart's contraction is felt in the arteries of the wrist, the temples, and some other parts of the body, and is called the *pulse*.

During the *pause* the relaxed walls of the heart yield to the blood which flows into the auricles from the pulmonary veins and the venæ cavæ. The semilunar valves at the

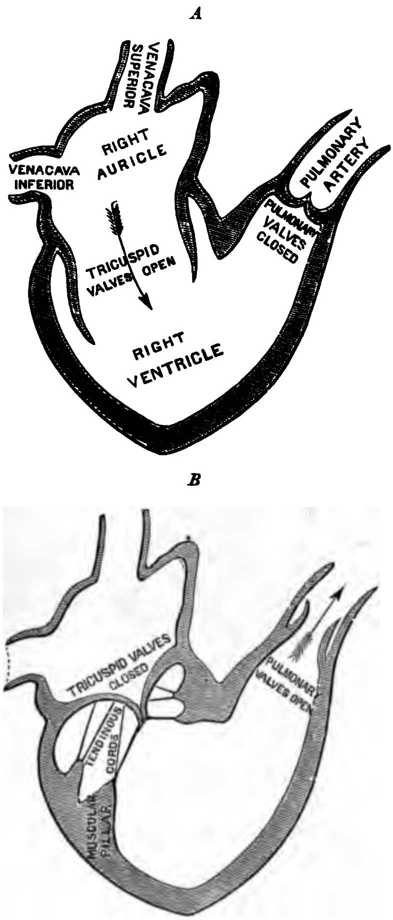


Fig. 96. — Diagrams illustrating the actions of the valves of the heart.

A during the filling of the right ventricle.
B during the contraction of the ventricle.

mouths of the great arteries are closed; the tricuspid and mitral valves are open. The ventricles now begin to dilate, and the blood flows freely into them from the auricles. As they fill, currents in the blood along the walls carry up the flaps of the valves till they are nearly closed. The auricles now contract, the contraction beginning at the mouths of the great veins, which narrows the openings, and more blood is sent into the ventricles. This swifter flow into the ventricles sets up stronger back currents along their walls, and, the muscular walls beginning to contract, the valves are completely closed. The blood then has no escape but by the arteries issuing from the ventricles. The strong walls of the ventricles press more and more upon the imprisoned blood, it is forced swiftly through the mouths of the arteries, pressing back the semilunar valves, and the ventricles themselves are empty before they begin to relax again. When relaxation sets in, the return of arterial blood into the ventricles is prevented by the semilunar valves.

231. Sounds of the Heart.—Two distinct sounds from the heart may be detected by placing the ear over the region of that organ. The first is dull and somewhat prolonged, the second is shorter and sharper. The first may be heard immediately before the pulse is felt at the wrist, the second immediately after it. They are followed by a brief silence. The exact cause of the first sound in not fully determined, but it is thought that it may be partly due to vibrations of the tendinous cords attached to the heart valves themselves, and partly to a muscular sound produced by contraction in the mass of muscular fibers in the ventricles. The second sound occurs at the moment of closure of the semilunar valves, and is due to the striking together of those valves.

232. Action of the Arteries. — All the blood vessels are always full of blood, — at the moment of the heart's pause, as at every other. When, therefore, the contraction of the left ventricle forces from four to six additional ounces of blood into the aorta, that which already fills the vessels must be crowded on. In the minute tubes of the capillaries there is, however, a very considerable amount of friction to be overcome, and as beat follows beat, the elastic walls of the arteries must stretch to receive the flow. The elastic arteries also react upon the blood between the beats to force it through the capillaries. Thus the flow, which is intermittent in the arteries, becomes continuous in the capillaries.

The muscular contraction in the arteries helps to regulate the amount of blood sent to different parts at different times. Many familiar facts illustrate this. Blushing is due to an increased flow of blood to the face; a mustard plaster draws more blood to the area which it covers; friction of the surface has a like effect. After death the arteries are always found empty, their last contraction having forced the blood into the veins.

233. Blood Pressure. — During life the elastic walls of the arteries are always distended, and the pressure upon their walls of the extra quantity of blood forced into them by the beating of the heart is called *blood pressure*. When an artery is cut, it is noticed that the blood issues from it in jets corresponding to the beats of the heart, and the nearer the cut is to the heart, the stronger is the spurt. When a vein is severed, on the other hand, the flow is steady and with less force.

The difference in the amount of blood pressure in veins and arteries is shown by experiments upon animals. If a long glass tube be introduced into the carotid artery of

a rabbit, for instance, the blood will rise in the tube to a height of about three feet, and will be raised slightly farther at each beat of the heart. If a similar tube be placed in an opening in the jugular vein, the blood will rise in the tube only very slightly, and the height will not be affected by the heart beats.

234. Velocity of the Blood. — Of course the same quantity of blood flows through the aorta as flows through all the capillaries of the system and is returned to the right auricle; but all the capillaries together hold much more blood than the aorta. The blood must, therefore, pass more rapidly through the aorta than through the capillaries. Its rate is about fifteen inches a second in the aorta, and about half that in the two venæ cavæ, while in the capillaries it is thought to be less than one twentieth of an inch in a second.

235. The Lymphatic Circulation. — We have seen (§ 209) that the plasma of the blood which oozes through the thin walls of the blood capillaries forms the fluid called *lymph.* This fluid contains corpuscles apparently identical with the white blood corpuscles, but no red ones. As it fills the spaces between the cells of the tissues it conveys nutriment directly to the cells themselves in all parts of the body. A network of delicate vessels called *lymph capillaries* carries away the surplus fluid. The walls of these tubes are extremely thin, being composed, like the blood capillaries, of a single layer of flat cells with a little connective tissue and a few plain muscular fibers. The small vessels unite to make up larger ones, which are supplied with valves, like the veins, and all finally pour their contents into two large tubes. One of these is called the *thoracic duct*, and runs upward in the thorax and abdomen along the spinal column to empty into the angle of junc-

tion of the large jugular vein in the neck with the left subclavian (Fig. 97). The other is the *right lymphatic duct*, and opens into the angle of junction of the right internal jugular and subclavian veins. The thoracic duct receives on its way the contents of the *lacteals*, and the whole is poured into the blood stream. Lymph is an alkaline fluid, and contains a larger proportion of the waste products of the vital processes than does the blood.

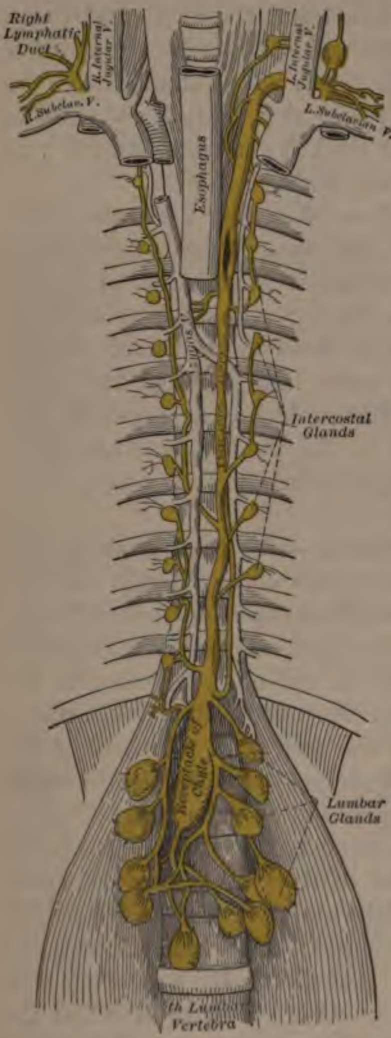


Fig. 97. — The thoracic duct and right lymphatic duct.

Nervous connection between the muscular fibers of the lymphatic vessels and the nerve centers has not been traced, though from what is known of nervous control over other organs and processes in the body, it is believed to exist.

236. Lymphatic Glands. — Throughout the lymphatic system colorless or white corpuscles are

found. Some of these pass through the walls of the blood capillaries with the plasma which forms the lymph, but all along the course of the lymphatics are small glands made of networks of connective tissue which hold in their meshes large numbers of small white corpuscles packed side by side as closely as possible. The lymph, flowing into these glands on one side and from them on the other side, carries along with it some of these corpuscles and thus keeps the blood supplied. These lymphatic glands, or similar tissues in the body, are the source of the white corpuscles of the blood.

237. Hygiene of the Circulation. — In perfect health the blood circulates rapidly, because the heart beats strongly, the muscular *tone* of arteries and veins is such as to promote the flow, the blood is purified in the lungs by an abundant supply of pure air, plenty of fresh material is supplied to it from suitable, well-digested food, the nervous centers are quickly responsive to their natural stimuli, and furnish the needful impulse to the numerous parts of the circulatory apparatus.

The blood cannot circulate freely unless the whole body is so loosely clothed that there is no pressure upon any of the blood vessels, no restriction of the breathing capacity, no interference with the normal action of the stomach, liver, and intestines. There must be exercise of all the muscles, sleep sufficient to keep the nervous system in good condition, and activity of the excretory organs. The last is promoted by exercise, frequent bathing, friction of the skin, and the wearing of woolen undergarments.

238. Effects of Alcohol upon the Blood and the Circulation. — The first effect of dilute alcohol taken into the stomach appears to be to make the heart beat faster and with

more force, to expand the smaller blood vessels of the skin, and to cause a more rapid flow of blood to the surface. This produces a comfortable glow in the skin, and the drinker thinks he has been warmed by his glass of wine or beer or weak spirits. As a matter of fact, however, most of the additional heat brought to the surface by the increased flow of warm blood very soon passes off and is followed by chilliness; for the general bodily temperature, though at first raised by the oxidation of the alcohol, is finally lowered by the increased radiation from the surface.

Alcohol in the stomach is rapidly absorbed and passes into the blood stream. There the strong affinity of alcohol for oxygen, which leads them to enter very rapidly into chemical combination, causes the alcohol to appropriate the oxygen of the red corpuscles of the blood, which, as we have seen (§ 205), are the great oxygen carriers in the body. This tends to impoverish the blood and render it less valuable to the tissues.

The immediate stimulation to the heart's action soon passes away and, like other muscles, the muscles of the heart lose power and contract with less force after having been excited by alcohol.

239. Effects of Tobacco upon the Circulation. — The frequent use of cigars or cigarettes by the young seriously affects the quality of the blood. The red blood corpuscles are not fully developed and charged with their normal supply of life-giving oxygen. This causes paleness of the skin, often noticed in the face of the young smoker. Palpitation of the heart is also a common result, followed by permanent weakness, so that the whole system is enfeebled, and mental vigor is impaired as well as physical strength. Observant teachers can usually tell which of

the boys under their care are addicted to smoking, simply by the comparative inferiority of their appearance, and by their intellectual and bodily indolence and feebleness. After full maturity is attained the evil effects of commencing the use of tobacco are less apparent; but competent physicians assert that it cannot be safely used by those under the age of forty.

Demonstrations and Experiments

75. *Dissection of the Heart.* — Order of a butcher the heart of a calf, sheep, or pig. Explicit directions should be given that the entire "pluck" be saved, *i.e.* heart, lungs, and larger blood vessels *intact;* otherwise mutilated specimens will be received. By inflating the lungs through the trachea their structure and general relationship to the heart can be shown. Observe that the heart lies in a sac, the pericardium. Cut open the latter and notice the pericardial fluid. Before proceeding to cut open the heart identify as many as possible of its parts and connected blood vessels. Observe the blood vessels connecting the heart and the lungs, and distinguish between the pulmonary artery and the pulmonary veins. The aorta and the two venæ cavæ can be distinguished with very little trouble. After severing the vessels connecting the heart with the lungs, the course of the blood through the heart can be shown, and a difference between the arteries and the veins can be demonstrated by forcing water into the vessels. Water injected through the venæ cavæ into the auricle emerges from the pulmonary artery. Injected in the opposite direction the flow is retarded by the auriculo-ventricular valve. In this way one can identify vessels of which he is in doubt, and demonstrate the functions of the valves. Demonstrate the internal structure of the heart by making incisions in the walls of the auricles and ventricles, and identifying the parts as described in the text.

76. *Demonstration of the Organs of Circulation.* — The principal vessels of the circulatory system can be readily dissected out in the body of a cat, dog, or rabbit. If the teacher is familiar with methods of injecting the circulatory system with some colored substance, the vessels can be more easily traced out, and also preparations can be

made that will keep permanently in suitable preservative fluids. But the larger blood vessels can be easily dissected out in uninjected specimens.

77. *Structure of Blood Vessels.* — Prepared cross sections of the walls of blood vessels can be purchased, or borrowed from some local physician. The blood vessel is seen to be composed of three coats: inner, epithelial; middle, largely muscular; and outer, fibrous.

78. *Circulation in the Web of the Frog's Foot.* — The frog should be placed in a small cloth bag, one foot being allowed to protrude. The animal should then be tied upon a board or wooden frame with the web of its foot stretched over an opening in the board. The web may be kept stretched by the aid of strings tied to the toes. The apparatus should then be placed so that the web over the hole in the frame lies directly under the objective of a compound microscope. If the animal, and especially the web of the foot, be kept moist, and the cords confining it are not too tight, the movements of the blood corpuscles can be studied for a long time. The experiment may be performed with little discomfort to the frog.

79. *Valves in Veins* can be shown by pressing firmly with the finger upon one of the veins of the forearm, and then passing the finger up along the vein toward the hand. The positions of the valves are indicated by the temporary swellings that make their appearance as the blood is forced back against the flaps of the valves.

80. *Scheme of the Circulation.* — The general features of the circulation can be illustrated with the apparatus shown in Fig. 98. The mechanism can be easily constructed, requiring only some rubber and some glass tubing, a few glass Y-tubes, some pinchcocks, and a bulb syringe.

81. *To illustrate Arterial and Venous Pressure and Flow.* — Remove the clamp from tube *C*, and force water through the apparatus with quick, regular strokes. The mercury in the manometers rises and falls with each stroke, and the water issues in jets from *E*. Clamp *C*. and continue as before. The mercury in manometer *M* oscillates but rises higher than before, with a marked excess of rise over fall, so that finally the mercury in one limb of the manometer stands at a considerable height, showing vibrations with each stroke of the pump. In manometer *N* the mercury rises slowly, with little or no oscillation, but the pressure is not so great as in *M*. The water issues from *E* in a steady stream. Open clamp at *D*; the water issues in jets corre-

sponding to the strokes of the pump. While working the pump press lightly with the finger on the rubber tubing of the arterial side; a distinct pulsation is felt with each stroke. Repeat the same on the venous side.

82. *Osmosis.* — Prepare a dialyzer by tying a thin animal membrane (sausage skins, to be obtained of a butcher, furnish excellent membranes for osmosis) over one end of a small lamp chimney. Partly fill the dialyzer with a strong solution of sugar and place it in a larger vessel of pure water, so that the liquids in the two vessels are at the same level. In a short time the contents of the dialyzer begin to rise, owing to the greater flow toward the denser liquid. It will also be found that the water in the outer vessel becomes sweet as osmosis goes on. If the membrane is allowed to become thoroughly dry after being tied on the dialyzer, osmosis goes on more rapidly.

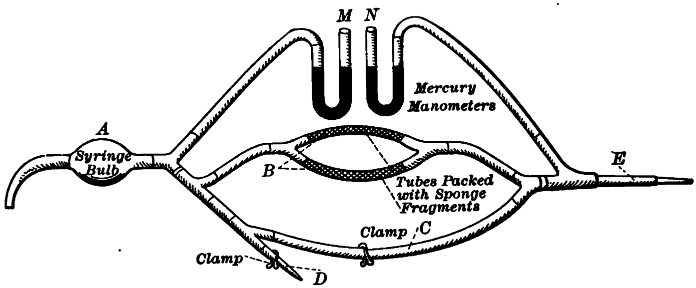


Fig. 98. — Apparatus for illustrating the circulatory system.

A bulb syringe, by which water is forced through the apparatus.
B rubber tubing packed with bits of sponge to represent capillaries.
C rubber tube connecting arterial and venous regions. When *C* is closed with the pinchcock the liquid must all pass through tubes *B*.
D small tube ending in capillary point and closed with a pinchcock. When open it allows arterial "spurting" to be demonstrated.
E tube which shows venous flow. It ends in a tube of small caliber in order to produce a venous pressure.
M, *N* manometers consisting of glass tubing bent in a U-shape and partly filled with mercury. They show the pressure applied to the arterial and venous sides respectively.

CHAPTER XIII

NERVOUS CONTROL OF THE CIRCULATION

240. Functions of the Nerves of the Circulatory System. — When any special activity is required of one of the organs of the body, an increased flow of blood is needful to that part. There is not blood enough in the body to enable all the muscles, all the organs of digestion, the brain, and the organs of respiration, etc., to work in full activity at the same time. There must therefore be some method of regulating the activities of the different parts and organs, so that some may rest while others work.

Then, too, some arrangement must exist for correlating the action of the heart and the blood vessels, so that the steady flow of nourishing blood may be kept up in all the capillaries, with more powerful pressure applied when and where it is needed, and not at the wrong place and the wrong time.

As everywhere else, we find that in the circulatory system the nerves furnish the controlling, coördinating, and regulating force.

241. Nerves of the Heart (Fig. 99). — Three sources of nervous control of the heart are usually mentioned. They are the *cardiac* or *heart branches* of the tenth and eleventh pairs of cranial nerves, — the *vagus* or *pneumogastric* and the *spinal accessory;* the *cardiac branches* of the *sympathetic*, from the ganglia of the neck; and what have

been called the *intrinsic nerves* of the heart, which were formerly treated as independent of the other two sets of nerve fibers. The intrinsic nerves are now known, however, to be merely the terminations of the other nerves in the heart wall, while the rhythmic beat of the ventricles, which is found to continue for some time even after the heart is removed from the body, is believed to be a peculiar property of the heart muscle itself.

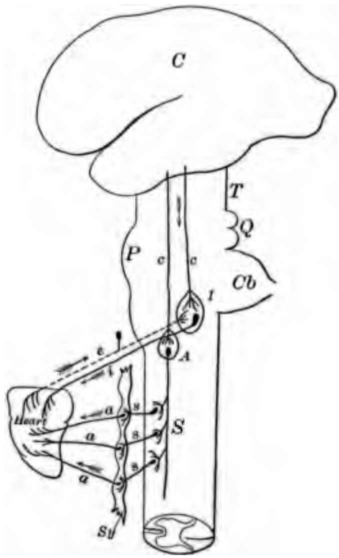


Fig. 99. — Diagram illustrating the nervous control of the heart.

A cardiac accelerator center.
a accelerator fibers connected with accelerator center through sympathetic system (*Sy*), spinal nerves (*S*), and spinal cord.
c fibers through which the cerebrum exercises control over the cardiac centers.
e fibers from the heart that excite the inhibitory center.
I cardiac inhibitory center.
i inhibitory fibers whose action slows the heart's beating.
s communicating fibers between spinal nerves and sympathetic system.
Sy sympathetic system.

242. Path of the Nervous Impulse. — The roots of the vagus and the spinal accessory nerves rise near together in the gray matter of the medulla oblongata. A branch from the spinal accessory soon joins the vagus, and supplies some of its motor or efferent fibers. Fibers from the sympathetic nerves of the neck also join the vagus. These have been traced back into the spinal cord. The cardiac nerves, therefore, are all connected with the central nervous system, and, since all parts of the

spinal cord communicate with the brain, they are all connected with the brain also. Certain fibers of the vagus proper carry the afferent influences from the heart to the brain, and by them the brain is kept informed of the heart's condition. Fibers of the spinal accessory and the sympathetic nerves convey motor impulses from the brain to the heart.

243. Accelerator Fibers of Cardiac Nerves. — Experiments have proved that it is the fibers from the sympathetic ganglia which convey to the heart the impulse which accelerates and strengthens its beat. They are supposed to run up the spinal cord to an *accelerator center* in the medulla oblongata (Fig. 99).

244. Inhibitory Fibers of Cardiac Nerves. — Stimulation of the fibers of the motor branch of the vagus running to the heart not only does not increase its action, but retards or *inhibits* it, and may entirely stop its beating. By this means the brain keeps a continual check upon the action of the heart. It has been found that if the vagus nerves of a dog are divided, the beat of the heart is quickened.

245. Reflex Inhibition. — A violent blow upon the stomach or abdomen, as is well known, may cause fainting, due to stoppage of the heart's action. The stimulus of the blow is carried by the sympathetic nerves of the epigastric plexus, situated around the pit of the stomach, to the thoracic ganglia and thence to the medulla oblongata. There the impulse is *reflected* along the efferent fibers of the vagus to the heart muscles, and their action is checked. Fainting may be caused in a similar way by the action of severe pain or strong emotion upon the nerve cells of the brain. The impulse reaches the region of the medulla oblongata from which the vagus arises, and is sent on to the heart.

246. Regulation of Blood Pressure in the Brain. — The regulation of blood pressure in the brain is by means of the inhibitory nerves. Excitement in the brain increases blood pressure there, and that pressure gives rise to inhibitory impulses by which the heart's action is restrained and danger to the brain is averted. Or, the inhibition may be a reflex impulse originating in the heart itself and sent up to the inhibitory center by the afferent fibers of the vagus, and the heart may be thus enabled to regulate its action according to its own necessities.

247. The Vasomotor Nervous System is that which regulates muscular action in the blood vessels. It belongs to the sympathetic system. The muscles of arteries and veins are composed of plain muscular fibers, and the nerves belonging to them appear to end in fine plexuses round the fibers. Two sets of nerves for the blood vessels have been made out, called the *vasoconstrictor* and the *vasodilator*, whose influences correspond to the influences of the accelerator and inhibitory fibers of the cardiac nerves. It should be noted that in the vertebrate animals no inhibitory nerve fibers exist in the nerves supplying the voluntary muscles, while the involuntary muscles usually have both accelerator and inhibitory fibers.

248. The Vasoconstrictor Nerves have been traced to the ganglia of the sympathetic chain and thence to the anterior horns of the spinal cord. From there fibers pass up to the *vasomotor center* in the gray matter of the medulla oblongata.

249. Vasodilator Nerves accompany the vasoconstrictor for a part of their course, and finally reach the same center in the medulla. They carry inhibitory impulses, that is, their action checks the contraction of the muscle fibers in the blood vessels and permits them to dilate.

250. Effects of Vasomotor Action. — The muscular action of the arteries gives its general *tone* to the arterial system and regulates the flow of blood in the whole body, and this general tone is influenced by the central nervous system. For instance, certain kinds of mental excitement which affect the brain result in dilation of the arteries of the face, which permits a more ample flow of blood to that part, causing what is called *blushing*. An opposite effect may be produced by emotion, causing *pallor*. The action is mainly reflex. So also in the case of the vessels of the skin. When the temperature is low, they are constricted and the surface becomes pale. As the temperature rises the vessels dilate and the skin becomes flushed. While these changes occur upon the surface, changes of a reverse order take place in the viscera, and the temperature of the body is thus largely regulated. Certain poisons in the blood circulating through the brain affect the vasomotor center, as when the blood is imperfectly oxygenated and therefore impure, resulting sometimes in suffocation.

251. Alcoholic beverages affect the delicate adjustment of the vasoconstrictor and vasodilator nervous forces and may seriously interfere with the circulation. As previously stated, dilute alcohol causes the constrictor muscles in the capillaries to relax so that the capillaries become dilated, and by the continued use of alcoholic drinks they may become permanently expanded.

CHAPTER XIV

RESPIRATION

252. Definition. — The lymph obtains from the blood in the capillaries and conveys to the tissues all that they need for sustaining their life. Their waste products are returned to the blood. One important element which all the tissues need, is oxygen, and one important element in the waste is carbon dioxide, or carbonic acid gas.

Respiration is the process by which oxygen is supplied to the blood and an excess of carbonic acid is removed from it. As a general term, respiration includes also the interchange of these gases in the tissues, called *internal respiration*, or tissue respiration, but the word is more commonly restricted to that part of the process which takes place in the lungs.

253. The Respiratory Apparatus consists of the channels through which air passes to reach the capillaries of the lungs, viz. *nostrils* and *mouth*, *pharynx*, *larynx*, *trachea*, *bronchi*, *bronchial tubes*, *alveoli*, and *air cells;* together with the *muscles of the chest*, *of the diaphragm*, and *of the abdomen.*

254. Normally the air enters the pharynx through the nostrils rather than the mouth. By passing through the winding passages of the nose it acquires nearly the temperature of the body, and is also relieved of some of the particles of dust always floating in the atmosphere.

255. The Trachea is a large tube of from sixteen to twenty incomplete cartilaginous rings (Fig. 100). It is from four to four and a half inches in length, from the

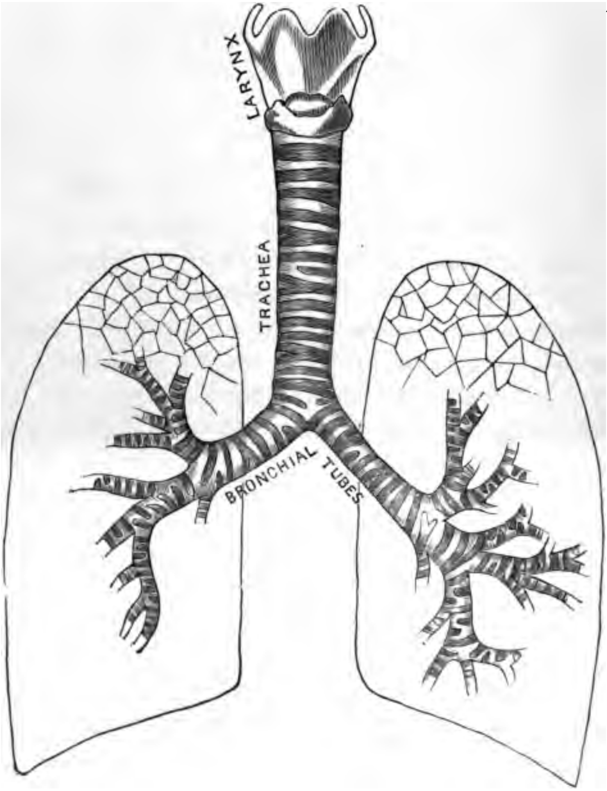


Fig. 100.—Diagram of the respiratory organs.

cricoid cartilage, to which it is attached above, to its lower extremity, where it divides into two *bronchi*, one of which goes to each lung. At the back of the trachea, between the ends of the cartilage rings. are bands of plain

muscular fiber, whose function is to draw the ends of the rings together and reduce the caliber of the tube. The whole tube is inclosed in a fibrous membrane, and lined, like the rest of the passages, with mucous membrane. The superficial layer of the epithelium of the trachea is *ciliated*, that is, supplied with minute hairlike prolongations.

256. The Bronchi resemble the trachea in structure, but have a distinct layer of plain muscle running around them.

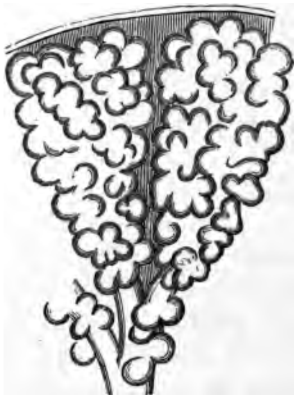


Fig. 101.—Two alveoli, showing the clusters of air cells.

257. The Bronchial Tubes and Alveoli. — The bronchi have numerous branches called *bronchial tubes* reaching to all parts of the lungs, each branch ending finally in a wider, funnel-shaped passage, the *alveolus*, surrounded by clusters of short, somewhat dilated sacs, the *air cells* (Fig. 101). All the tubes are lined, like the trachea, with ciliated epithelium. The cilia being continually in motion drive out the mucus which is constantly secreted, and along with it the dust brought into the passages with the air.

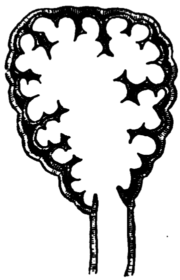


Fig. 102.—Section of an alveolus, showing air cells opening into the central cavity.

258. The Air Cells are the hollow expansions of the *alveolus* (Fig. 102). They have a lining of very fine epithelium, without cilia, and within that a close network of capillaries. In these the arteries of the lungs make connection with the veins.

259. The Lungs are made up of collections of air cells and the branches of the bronchial tubes. Their texture is spongy and elastic, and a piece of a lung, unlike any other tissue, will float in water. Each lung is enveloped in the *pleura*, which is a serous membrane folded back to form the lining of the diaphragm and the chest wall. The two layers of the pleura are in contact with each other, with only enough of the fluid secretion to enable them to glide smoothly over each other. Each lung is partly divided into *lobes*, there being three lobes in the right and two in the left lung (Fig. 86). Each lobe is also made up of many small parts called *lobules*, each containing a minute branch of a bronchial tube with air cells, blood vessels, nerves, and lymphatics. The air cells in the different lobules have no communication with one another, so that if one of the bronchial tubes is obstructed the cells opening into it are not supplied with air.

260. Blood supplied to the Lungs. — The blood conveyed to the lungs is from two sources: (1) The *pulmonary artery* from the right ventricle brings the impure blood, collected by the veins throughout the body, to be purified, or oxygenated. (2) The *bronchial arteries* bring pure arterial blood for the nutrition of all parts of the organ. This is returned through the bronchial veins, and in some measure also through the pulmonary veins.

261. Inspiration and Expiration. — The thorax is a closed cavity, and the air cannot reach the outside of the lungs, hence the pressure of the weight of the atmosphere affects the lungs only from the inside, and they are kept distended to fill the cavity. If the thorax is increased in size, the air rushes in and distends the elastic cells of the lungs still more. If the cavity of the thorax is reduced in size, the air is forced out, and the lungs are contracted.

It is the pressure of the atmosphere which causes the air to enter the lungs in what is called *inspiration*, and the pressure upon the lungs by the walls of the thorax which forces it out in *expiration*. These two acts together constitute *respiration*.

262. The Respiratory Mechanism. — In respiration the size of the thorax is increased in two ways: (1) by the depression of the diaphragm, which forms the floor of the cavity and separates it from the cavity of the abdomen; (2) by the elevation of the forward ends of the ribs.

263. The Diaphragm is a sheet of muscle and tendon, convex on its upper side, and attached by bands of striped muscle to the lower ribs at the side, to the sternum and to the cartilages of the ribs which join it in front, and at the back by very strong bands to the lumbar vertebræ. Its center is a thin expanse of tendon. When the muscles about the circumference contract, the arch is flattened upon the contents of the abdomen, which yield to its pressure, and the thorax is enlarged downward (Fig. 103).

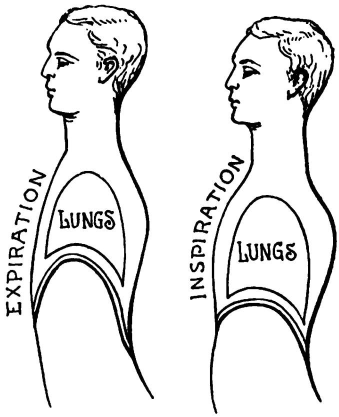


Fig. 103. — Diagram illustrating the varying position of the diaphragm during respiration.

264. Action of the Ribs and Muscles of the Chest. — The ribs are attached to the spinal column at an angle smaller than a right angle (Fig. 33, p. 45), and slope downward toward the breastbone, the lower ribs sloping more than the upper. When, by the contraction of the chest muscles, the sternum is drawn upward and outward, the ribs

are raised to a more nearly horizontal position, and the cavity they inclose is enlarged toward the front. At the same moment the ribs are rotated slightly at their articulation with the vertebræ, and by their curvature they enlarge the chest at the sides. Many muscles are involved in this complex action. The external intercostal muscles (the elevators of the ribs) and the muscles in the walls of the abdomen are principally concerned, but certain muscles of the head, neck, and back also assist, and in forced breathing many others are brought into use. In ordinary, quiet expiration, the elasticity of the chest walls, the cartilages, and the lungs is sufficient to expel the air inhaled without special muscular contraction. But in special, extraordinary efforts of expiration, as in coughing, sneezing, singing, etc., active muscular effort is required. For this purpose the muscles of the abdominal walls are chiefly brought into action, and by them the diaphragm is forced upward, the cavity of the thorax is made smaller, and the air is driven rapidly out of the lungs. When those muscles again relax, the chest returns to its normal size.

265. Effect of Respiration upon Air in the Lungs. — The lungs are always full of air, about two hundred cubic inches remaining in the lungs of an adult man after expiration. He draws in and breathes out in ordinary breathing from twenty to thirty cubic inches, and in forced respiration may take in and expel one hundred cubic inches more. By what is known as the *diffusion of gases* the inspired air is equally mixed throughout with that remaining in the air cells and tubes of the lungs, and there is no accumulation anywhere of air which has been deprived of oxygen. A similar interchange takes place through the walls of the capillaries between the gases in

the air of the lungs and those in the blood; and in the same way the oxygen passes from the blood to the tissues, while the carbonic acid passes from the tissues into the blood.

266. Atmospheric Air compared with Expired Air. — The atmosphere is composed of five gases: oxygen, nitrogen, argon, carbon dioxide, and watery vapor, the last varying greatly in relative amount according as the atmosphere is moist or dry. Helium and other recently discovered gases exist in the air in very small traces, but may be left out of consideration. Oxygen and nitrogen are the principal elements in air. The amount of carbon dioxide in outdoor air is very small.

Pure dry air contains in each one hundred parts 20.96 parts of oxygen, 78 parts of nitrogen, 1 part of argon, and .04 part of carbon dioxide. Expired air (breathed once) contains about 16 parts by volume of oxygen, 79 parts nitrogen and argon, and 4 parts carbon dioxide. There is, besides, in expired air, a considerable quantity of watery vapor, and a variable amount of volatile organic matter, not sufficient generally for chemical analysis to detect, but often perceived in a close room by the sense of smell.

It appears from the above that more than four parts of the oxygen is appropriated from the air in the lungs, and that about four parts of carbon dioxide, besides a minute amount of organic waste and some vapor of water, are given back to the air. The temperature of the expired air is very nearly the same as that of the body.

267. Effect of Respiration on the Blood. — The blood brought to the lungs by the pulmonary artery is dark purple in color, but that which is returned to the left auricle of the heart, after circulating through the lungs, is of a brilliant scarlet. The same difference is seen

between the bright arterial blood in the arteries and the dark venous blood of the veins of the systemic circulation. Chemical analysis shows that this difference in the blood corresponds to the difference between the air inspired and the air expired. The immense amount of capillary surface which the air reaches in the air cells of the lungs has taken from it a large amount of oxygen and has given up to it carbon dioxide and organic waste, together with some of the water in the venous blood of the capillaries. That is, the blood has been *arterialized* in the lungs, for (except in the pulmonary circulation, where the reverse is the case) the arteries convey the oxygenated, or purified, nourishing blood, while the veins are filled with the impure, partly deoxidized, and poisonous blood. In health both arterial and venous blood contain both oxygen and carbon dioxide, the proportion of oxygen being much larger in the arterialized blood.

268. Function of the Red Corpuscles. — It was stated in the chapter on the Blood that the special function of the *red corpuscles* is to take up and hold for a time a certain amount of oxygen, and then to give it up to other tissues. The red corpuscles, as we have seen, are chiefly made up of a red substance called *hemoglobin*, and hemoglobin which has absorbed a considerable amount of oxygen becomes *oxyhemoglobin*, which is of a bright scarlet color. Oxyhemoglobin becomes hemoglobin again and of a dark purplish red when it is deprived of its oxygen. When brought into contact with air in the lungs, the red corpuscles take up oxygen, while carbon dioxide is given up in return. The oxygen is held by the red corpuscles in loose combination, that is, in such a chemical union as is easily disturbed, the oxygen being readily given up *to form other* combinations.

269. Tissue Respiration. — The lungs were once regarded as the seat of the combustion of the body — as the furnace to which the waste of the body was brought to be burned up. It is now known that the tissues themselves are the seat of combustion, or oxidation. The oxygen given off to the tissues from the arterial blood in the capillaries is not necessarily used at once in new chemical combinations. In muscular tissue, and probably in other varieties of tissue, it is stored for future use. This is shown by the fact that severe muscular action, by which the substance of the muscle fibers is broken down in the production of energy, results in the elimination of carbon dioxide which contains more oxygen than the whole amount taken up by the lungs during the time of action.

It appears that the tissues are constantly taking oxygen from the blood (or, strictly speaking, from the lymph) and combining it in forms which are easily decomposed, and thus the oxygen is ready when it is needed for the liberation of energy. A man gives off from his lungs more oxygen in the form of carbon dioxide during the day, when his muscles, brain, and digestive organs are at work, than the lungs take up during the same time. The excess had been stored during his periods of rest. Although oxygen is that element in the air which supports life, it has been established by experiments that an animal uses no more oxygen in a given time when it breathes the gas pure than when it breathes ordinary air, that is, the amount of work done by the tissues is not determined by the amount of oxygen supplied to them, but the quantity of oxygen used is determined by the amount of work done. An excess of oxygen above that amount needful to prevent suffocation will not make the organs work any more than extra food will make a man work.

270. Necessity of Ventilation. — In each ordinary expiration of an adult man, from twenty to thirty cubic inches of air issue from the lungs, or in one hour about twelve cubic feet. This air has been deprived of a large proportion of its oxygen, which has been replaced chiefly by carbon dioxide. This carbonic acid, while not itself poisonous, at least in small quantities, is always associated in expired air with waste products of organic life which are so, and is a measure of their amount. To be fit for breathing, air should not contain more than one fifth of one per cent of carbon dioxide. Some authorities say one tenth.

It is found that in quiet breathing a man gives out something over 1000 cubic inches of carbon dioxide in an hour. If hard at work, he will expire two or three times as much. From 1000 to 3000 cubic feet of fresh air per hour for each occupant of a closed room should be supplied from outside the building, and in hospitals and workshops the amount should often be much larger. Persons vary greatly in their sensitiveness to impure air. Many become accustomed by long usage to dwelling in ill-ventilated rooms, and seem to suffer no immediate evil effects; when others coming from a purer atmosphere will experience dizziness, headache, or nausea.

271. Ventilation is the regular and continuous removal of the expired, vitiated air from a room and the admission of pure atmospheric air. To be adequate to human needs, it must bring into a room enough external air to dilute the poisonous products of respiration and of the combustion of gas, oil, or candles, together with the exhalations from the skin, to such a degree that the air of the room may remain pure enough for breathing.

The amount of air, by weight, inhaled by an average *person* in twenty-four hours is from six to eight times

that of the food which he eats, and it is at least quite as important that this air should be pure as that the food consumed should be wholesome.

Every expiration of each pair of lungs in a closed room reduces the quantity of oxygen in the room and increases the carbonic acid gas and other impurities. Now, experience and experiment have proved that the relative proportions of these gases in the air inhaled cannot be greatly changed without injuriously affecting animal organisms. The presence of 1 per cent of carbonic acid gas is harmful, though 1 per cent may be endured for a time; but it is the impurities always present with the gas, other than the carbonic acid gas itself, together with the increase of moisture and heat and unpleasant odors, that produce the bad effects. When the amount of carbon dioxide becomes 10 per cent death is only a matter of time.

A person may be suffocated to death in an ill-ventilated room from lack of oxygen, from an excess of carbon dioxide, or from the two causes combined, and he is also exposed to other dangers whose effects are not manifest at once. If several persons are present, germs of disease are liable to be floating in the air or clinging to walls or floor, and may easily be drawn into the lungs along with other dust. The diseases most often communicated in this way are consumption and pneumonia, each of which is believed to be caused by a specific bacterium.

272. Methods of Warming and Ventilation.— In some modern buildings, provision for ventilation is made in connection with the heating apparatus. Hot air furnaces provide for a constant flow of warm air into a room, with the removal of that already present. The danger is lest the air brought in should be taken not from pure outdoor sources but from cellars, or from rooms where it has been already vitiated,

or from openings too near a cesspool or sewer pipe. Houses warmed by the circulation of steam or hot water must have independent arrangements for ventilation by means of open fireplaces or chimney flues, and adequate openings for admitting pure air. The same may be said of houses heated by ordinary air-tight stoves, or by oil and gas stoves. The latter, while making no provision for ventilation, increase the need of it by their combustion.

When adequate provision for ventilation is not made in the construction of a building, fresh air may be admitted, without causing a direct draught, by fitting a board six or eight inches wide under a raised window sash, so that the exchange between internal and external air may take place between the sashes. Such an arrangement is useful in schoolrooms and other places of assembly. Care should be taken to avoid a draught of cold air, which is sometimes more immediately dangerous than to breathe vitiated air for a little while. At the same time it should not be forgotten that the worst effects of breathing impure air do not appear at once. While it is a direct cause of pulmonary consumption (the greatest scourge of the human race) and other ills, it may be a long time before disease appears. The vitality of the system is gradually lowered, strength and vigor are undermined, so that some slight overexertion or exposure to cold or to specific germs of disease may result in serious or fatal consequences. When the whole system is kept by correct habits of life at a high level of health, when all the parts work vigorously, easily, and in harmony, one is able to endure unharmed exposure even to active germs of malignant diseases.

273. Correct Breathing. — One can breathe properly only when the clothing is loose enough to allow entirely free

movement of all the muscles concerned in respiration. It has been noticed that men and infants use the abdominal muscles and those of the lower part of the chest more than women do. This is not because women have a sort of breathing apparatus different from that of other human beings, but because their clothing is too frequently worn so tight that full and free respiration is impossible, the various organs being displaced and deformed, and the whole system weakened, while to the artistic eye the figure appears distorted and ugly.

One should accustom himself to go often into the open air and draw long, full, and deliberate breaths, followed by slow expiration, in order that all the minute air cells of the lungs may be filled and their walls expanded. Those which are habitually unused may become permanently collapsed and hardened, and the capacity of the lungs be thus reduced, the whole system being weakened and prepared to fall an easy prey to disease.

274. Temperature of Air for Breathing. — Man is able to live a healthy life in the most torrid climates and in regions where the air is many degrees below the freezing point. He can even remain for some time unharmed in a chamber heated far above the boiling point of water. Such are the marvelous adjustments of which his organism is capable.

But in connection with the artificial warming of closed rooms, it is necessary to inquire as to the most healthful temperature of the air habitually breathed. Most people in America live, in winter, in rooms too hot for health, and thus render themselves unnecessarily liable to "take cold" on going out. A living room for adults in ordinary health should have a temperature of from 65° to 70° F. (18° to 21° C.). For young children, the aged, or the

feeble the room may be a few degrees warmer. Sleeping rooms should usually be much colder, but definite rules cannot be given. Much depends upon habit, age, and state of health. To live always in a warm atmosphere is enervating. Cold air, when pure, is far more refreshing and invigorating. It is highly desirable to accustom one's self to sleep with open windows in all seasons.

275. Respiration as affected by the Use of Alcohol and Tobacco. — The action of alcohol upon the muscular walls of the arteries, which has been already more than once referred to, is especially important in the capillaries of the lungs. When they are dilated by the paralyzing effect of alcohol, their expansion reduces the size of the air cells in the lungs and leaves less room for the air which the lungs need, so that less oxygen is supplied to the blood. When the capillaries are often or continuously distended in this way, their walls are likely to become permanently thickened, and the interchange of gases which normally takes place there, by which carbon dioxide passes from the blood while the purifying oxygen is taken into the blood, is impeded. Serious disease even may result, such as a peculiar and quickly fatal form of consumption found only among drinkers of alcoholic fluids.

The throat, bronchial tubes, and lungs of a tobacco smoker are all liable to irritation by the poisonous smoke, and chronic inflammation is often caused. The nicotine of tobacco is a deadly poison, and in cigarettes there are often other poisons equally dangerous to health.

Demonstrations and Experiments

83. *Dissection of the Respiratory Organs.* — The thorax of a rabbit, *cat, or dog* will be found serviceable. Before cutting open the chest,

the arrangement of the ribs, intercostal muscles, and connected parts should be noticed. When the thorax is cut open the lungs collapse. Observe the relation of the heart to the lungs. Inflate the latter through a tube inserted in the trachea. Observe the diaphragm; note its shape in contraction and relaxation. Cut open the lungs and trace out in them the subdivisions of the bronchial tubes. The structure of the trachea and larynx should be carefully studied.

84. *To illustrate the Action of the Diaphragm in Respiration.* — Tie over the large end of a stoppered bell jar, or of a large bottle whose bottom has been removed, a piece of thin rubber cloth (Fig. 104). Close the smaller opening of the jar with a cork, through which runs a glass tube, on whose inner end a thin rubber bag is tied, as shown in the figure. Then, if the rubber bottom be pushed in, the bag will collapse. When the bottom is allowed to return to its first position, the bag expands. The rubber bottom represents the diaphragm, and the small rubber bag and the glass tubing the lungs and trachea, while the jar itself represents the thorax. If the lungs and trachea of a small animal be carefully dissected out, they may be used to replace the small rubber bag by tying the glass tube in the trachea. In this way may be shown the movements of the lungs themselves in respiration. Another form of apparatus for demonstrating the action of the diaphragm in respiration is shown in Fig. 105, in which the bell jar and rubber cloth of Fig. 104 are replaced by a lamp chimney and a piston. (The piston can be made of a wooden stick with a piece of wet cloth tied around the large end.)

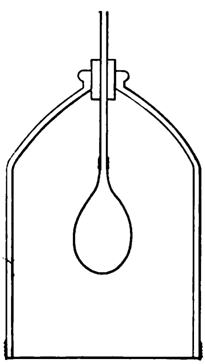


Fig. 104. — Apparatus to illustrate the action of the diaphragm in respiration.

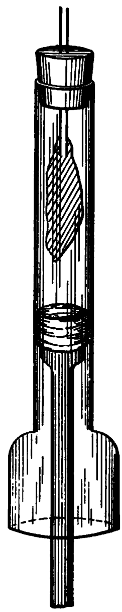


Fig. 105. Apparatus to demonstrate the action of the diaphragm in respiration.

85. *To illustrate the Function of the Ribs in Respiration.* — Construct a

piece of apparatus as shown in Fig. 106. The standard *AB* represents the vertebral column; the two pieces *CD* and *EF* represent two of the ribs, with *DF*, a portion of the sternum, attached; *a* and *b* are rubber bands representing the external and internal intercostal muscles respectively; *c* is a rubber band of such strength that it keeps the

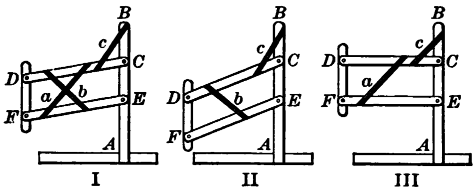


Fig. 106. — Apparatus to illustrate the movements of the ribs and sternum in respiration.

apparatus in position I when the rubber bands *a* and *b* are both on. Remove the rubber band *a*; *DF* is lowered. Replace *a* and remove *b*; *DF* is raised. Observe that when *DF* is raised from position II, the distance between *DF* and *CE* is increased, unless *DF* is raised too far.

86. *To show the Moisture in Respired Air.* — Breathe upon a cool plate of glass; some of the vapor in the breath will be condensed upon the glass. To show that the presence of moisture is due to respiration, blow upon the glass with bellows.

87. *To show that Air is made Warmer in Respiration.* — Notice the reading of a thermometer, then breathe upon its bulb.

88. *Some Properties of the Constituent Gases of Air.* — The teacher should prepare oxygen, nitrogen, and carbon dioxide by methods given in ordinary text-books of chemistry. Place a smoldering splinter of wood in a vessel of oxygen; the stick bursts into flame. Place the flaming splinter in a vessel of carbon dioxide or nitrogen; the flame is at once extinguished. Place a blazing splinter in an empty jar, *i.e.* containing only air; after burning some time it goes out. Before the last trace of fire disappears, transfer the splinter to a jar of oxygen; it burns actively again. Into a clean, empty jar put a little limewater, prepared by dissolving lime in water. Cover the jar and shake it well; if any considerable amount of carbon dioxide is present, a white precipitate will form in the limewater. Now place a burning splinter in the jar and allow it to burn out. Then shake

the jar; the presence of carbon dioxide will be very evident. Repeat the latter operation after allowing splinters to burn out in a jar of oxygen. From these experiments it becomes evident that oxygen is necessary in ordinary combustion, and that carbon dioxide is a product of combustion.

89. *To show that Respiration increases the Amount of Carbon Dioxide in the Air.* — By means of a glass tube blow through limewater; the white precipitate of carbonate of lime shows the presence of carbon dioxide in the breath. To show that most of this is a product of respiration, pass some of the ordinary air of the room through lime water; the white precipitate is much smaller in amount.

90. *To illustrate a Difference between "Arterial" and "Venous" Blood.* — Obtain some fresh ox blood at a slaughterhouse and "whip" it to remove the fibrin and prevent clotting. By means of a carbon dioxide generator, pass carbon dioxide gas through the blood; the blood becomes darker. Now pass air through it, thus supplying oxygen; it becomes more scarlet in color.

CHAPTER XV

NERVOUS CONTROL OF THE RESPIRATORY APPARATUS

276. The movements of respiration may go on in ordinary quiet breathing without consciousness and without volition, but they are also, in a measure, under voluntary control — not wholly so, for it is impossible to commit suicide by holding the breath.

277. The Respiratory Center and Nerves (Fig. 107). — A certain restricted area in the medulla oblongata is recognized as the *respiratory center*, and there are believed to be other such centers lower down in the spinal cord. Nervous impulses pass from the center down the spinal cord, and thence by the anterior roots of many of the spinal nerves to the plexuses which those nerves form. By communicating branches from these plexuses connection is made with the spinal ganglia of the sympathetic system, and with the tenth and eleventh cranial nerves. From these various sources motor fibers pass on to the numerous muscles concerned in respiration. That which supplies the diaphragm is the *phrenic nerve*, which is traced back to the three or four upper pairs of spinal nerves.

If the spinal cord be divided below the fourth pair of spinal nerves, the diaphragm will continue to act, but the intercostal muscles will be paralyzed. If the cord be cut just below the medulla oblongata, all respiratory movement *of the chest* ceases; and if that small portion of the medulla

oblongata known as the *respiratory center* be removed, no further respiratory movements will take place, and death immediately follows. On the other hand, the whole of the brain forward of the medulla may be removed, and breathing will not stop.

278. The Expiratory Center. — It is now understood that the center of respiration in the medulla is in reality double,—that there is one center for inspiratory movement and another beside it for expiratory movement. In ordinary quiet breathing the first only is excited, expiration taking place by the relaxation of the muscles contracted in inspiration. But in violent or forced expiration the internal intercostal and abdominal muscles are brought into active use, and the nervous influence stimulating them to action comes from the *expiratory center*.

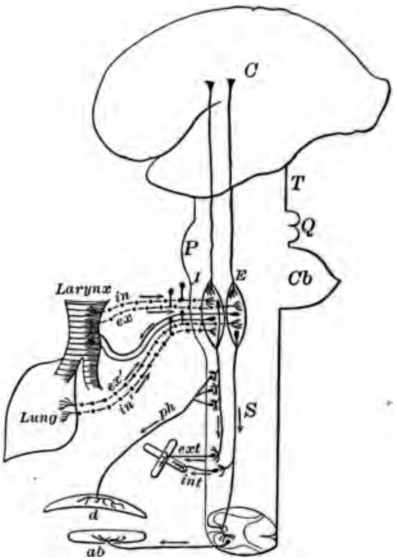


Fig. 107. — Diagram of the nervous control of the respiratory organs.

ab motor spinal nerves going to muscles of the abdominal walls.
E expiratory center.
ex sensory nerve fibers from the larynx exciting the expiratory center.
ex' sensory fibers from the lungs exciting the expiratory center.
ext motor spinal nerve fibers passing to external intercostal muscles.
I inspiratory center.
in sensory fibers from larynx inhibiting the inspiratory center.
in' sensory fibers from the lungs that excite the inspiratory center.
int motor spinal nerve fibers passing to internal intercostal muscles.
ph motor fibers of phrenic nerve going to diaphragm.

279. Reflex Action of Respiratory Center. — Though the action of the breathing center in the medulla oblongata is shown by experiment to originate efferent nervous impulses independent of irritation conveyed to it by sensory fibers, it is also largely under reflex control. For instance, when the mucous membrane of the air passages is irritated by foreign substances, a sudden sneeze or cough results. A sudden dash of cold water upon the skin causes a quick, long inspiration. So it appears that in normal respiration the movements are not reflex, while reflex movements are also possible.

280. The Normal Excitation of the Respiratory Center is due, more than to any other cause, to the relative amounts of oxygen and carbon dioxide in the blood which reaches it. If the blood contains too little oxygen and too much carbon dioxide, the center is stimulated, and the resulting respiratory movements tend to correct the evil.

Afferent nervous influences brought to the center along the vagus nerves also excite its action. The main trunk of this tenth nerve contains fibers which excite inspiration, and other fibers which inhibit, or check, inspiratory movements. It is supposed that the expansion of the air cells in the lungs, where many of the vagus fibers end, produces impulses along those fibers which result in inhibitory or expiratory impulses from the center in the medulla; while, on the other hand, collapse of the air cells excites along other fibers contrary impulses which result in inspiration. Thus the action of the lungs becomes that of a self-regulating pump. Other afferent impulses along branches of the vagus, or from other nerve fibers connected with it, may also affect respiration.

CHAPTER XVI

FOOD

281. Losses of the Body. — One effect of respiration is to reduce the weight of the body. A man gives off from the lungs, in the course of twenty-four hours, about eight ounces of carbon and about half a pint of water, which are taken from the tissues of the body as worn-out materials. There are also other sources of loss to the body in the processes of excretion, by which the waste or used-up matter of the body is cast off.

282. Sources of Restoration. — These losses must, of course, be made good, or the body will waste away. Through the lungs we get oxygen only, while we need hydrogen, nitrogen, carbon, and other chemical elements besides, which enter into the composition of our bodies. These come to us in the *food* which we eat, and are prepared for use within the body by the process called *digestion.*

Food is that which, taken into the alimentary canal, supplies material for the growth and repair of tissue, for the generation of force, or for the regulation of force.

283. Nutrition. — Digestion is but one portion of a complicated series of processes, called *nutrition*, which result in the growth and repair of the constantly wasting tissues. In its broad sense nutrition includes *respiration*, which supplies the oxygen needed; *digestion*, or the conversion

of food by the chemical action of the digestive juices into soluble substances ready to be acted upon by the absorbents; *absorption*, or the passage of selected elements from the digested food through the walls of the blood vessels and lymphatics (lacteals); *assimilation*, or the conversion of the new particles of food into the substance of the tissues of the body; and the breaking down of the substance of the tissues to form *waste*. The building-up processes constitute what is called *anabolism*, the breaking down of tissue *katabolism*, while the whole double operation receives the scientific name of *metabolism*. We are now to study anabolism.

284. Object of Nutrition. — The various processes of nutrition take place in order to supply the human machine with material in suitable form for the production of energy. The oxidizable substances are distributed to the tissues and are there submitted to the action of the oxygen in the blood. *Combustion* then takes place, that is, the substances in the tissue cells are *burned*. The complex chemical compounds there found are decomposed, and new and simpler compounds are formed, which being of no further use to the body are removed from it by mechanisms prepared for the purpose.

285. Forms of Energy in the Body. — The force set free in the tissues by the combustion of their particles takes many forms within the body, but as it leaves the body it appears in two forms only: as heat or as work done by the muscles. Just as matter may be changed from one form to another, but cannot be destroyed, so energy, or force, may be changed from one form to another, but cannot be destroyed. The heat driven off in the combustion of coal may be changed through the agency of steam into the motion of machinery, which may in turn be con-

verted into electrical force or light, or again become heat. A mechanic's blow upon an anvil converts muscular force into motion, heat, and light. Any form of energy must result from some other form of energy. It cannot come from nothing.

286. Conservation of Energy and Correlation of Forces. — These facts, in works upon the science of physics, are stated as the laws of *conservation of energy* and of *the correlation of forces.* The human body, like all other matter, is subject to these laws.

As the power for a large proportion of our machines comes from the heat of combustion, — that is, the union of oxygen with other matter, — so does the energy of the body come mainly from the same chemical action, and the products of the slow combustion of food which takes place within the body are much the same as they would be if the food were burned in a furnace by swift combustion. Those products are carbon dioxide, water, and a nitrogen-containing substance which is discharged from the body as urea, besides certain salts not oxidizable which would appear in the furnace as ashes.

287. Food Elements. — The valuable parts of the matter which we call food enter in varying proportions into many different articles which we eat. Chemists divide these elements, which are essential to the maintenance of the body in health, into five classes, as follows : —

<table>
<tr><td>1. Proteids</td><td>(Nitrogenous foods)</td><td rowspan="3">Organic</td></tr>
<tr><td>2. Carbohydrates</td><td rowspan="2">(Nonnitrogenous)</td></tr>
<tr><td>3. Fats</td></tr>
<tr><td>4. Water</td><td rowspan="2">Inorganic</td><td></td></tr>
<tr><td>5. Salts</td><td></td></tr>
</table>

Milk and eggs are examples of food containing all these materials in proportions suitable for young, grow-

ing animals, and they are therefore spoken of as "perfect foods."

288. Characteristics of a Healthful Diet. — (1) A healthful diet must contain all five chemical classes of food elements in due proportion. (2) It must be adapted to the climate, to the age of the individual, and to his mode of life, that is, to the kind and amount of work which he does. (3) Not only must the different kinds and amounts of necessary food appear in the diet, but they must appear in digestible form.

289. Classification of Foods. — With reference to the use made of them, foods are divided into three classes: (1) tissue builders; (2) force generators; (3) force regulators. The proteids constitute the first class, though we are not certain but that they may be sometimes oxidized, yielding force without having entered into the composition of living cells. In the second class are placed the oxidizable substances, — the fats and carbohydrates. They may also assist in forming tissue to some extent. The third class includes the inorganic compounds, — water, salts, etc., — and certain *food accessories.*

290. Proteids are the most important substances which enter into the animal organism, being absolutely essential to the phenomena of life. Plants are the great manufacturers of proteids; no process has yet been discovered for making them artificially. Proteids are complex chemical compounds and are characteristically represented by the *casein* of milk and the *albumin* of egg. All are composed of carbon, hydrogen, nitrogen, and oxygen in various proportions, with a trace of sulphur. Proteids are the only group of foods which contain nitrogen, and whose chief if not sole purpose is the building of tissue. *Animals can live* without carbohydrates and fats, but not

without proteids. The chief proteids are the *gluten* of all cereals, peas, potatoes, beans, and lentils; the *albumin* in white of egg, milk, and blood; *globulin* from yolk of egg and blood; *myosin* found in lean meat; *casein* in milk and cheese; *fibrin* in clotted blood. Though certain vegetables (as beans and peas) contain more proteid than does meat, they furnish it in a less digestible form, that is, a considerable part of it passes from the body unaffected by the digestive processes, and the proteid of these vegetables is therefore less valuable as food.

Since only the proteids contain nitrogen, they are called *nitrogenous foods;* and carbohydrates and fats are called *nonnitrogenous.*

A healthy, well-fed animal is found to lose by excretion as much nitrogen daily as is supplied in his food. If the food contains an insufficient amount of nitrogen, the quantity excreted is greater than that received, and the tissues waste away.

291. Fats are found in butter, milk, cheese, and meat, in some of the grains, and in oils. They contain carbon, hydrogen, and oxygen. They are oxidized in the body, and furnish energy and heat.

292. The Carbohydrates, like the fats, contain carbon, hydrogen, and oxygen; but the proportion of oxygen is larger than in fats. The carbohydrates include (1) *starch,* which is found in cereals, vegetables, nuts, etc.; (2) *sugars* of different kinds,—grape sugar, cane sugar, malt sugar, and milk sugar, besides sugar manufactured from starch; and (3) *cellulose,* found in fruits, cereals, and all vegetables. Carbohydrates are very rapidly oxidized in the body, producing heat, and it is they that are used up in the setting free of energy when the muscles are vigorously exercised; for it is found that the nitrogenous waste does not increase

in proportion to the increase of muscular effort. Carbohydrates cannot alone form tissue, but under some circumstances may be used for that purpose with other elements.

293. Water, composed of oxygen and hydrogen, is found in all foods, and has a variety of uses in connection with nutrition, partly as a solvent for various elements in the food, and partly as promoting osmosis, and as an aid to the varied changes which take place in the tissues. Water uncombined with food, introduced into the stomach as in drinking, is all absorbed directly into the blood, of which it forms about 80 per cent.

294. Salts. — The food elements that are salts are chiefly the chlorides, phosphates, and carbonates of sodium and potassium, and to a less extent those of calcium and magnesium, with salts of iron and of some of the organic acids. Common salt (chloride of sodium) appears in all animal bodies, and to some extent in plants also. It helps to dissolve certain of the albumins of the body, promotes the flow of the digestive fluids, and aids digestion in various ways. About half an ounce each day is needed with the food. That these saline matters are essential to health, is proved by experiments upon animals. When they are eliminated so far as possible from the diet, the central nervous system soon suffers, and paralysis results, besides general derangement of nutrition. When an animal body is burned, the various salts which entered into its composition appear in the ashes which are left, while the other substances have been changed into gases.

295. Food Accessories. — These are the various *drinks* — alcohol in different forms, tea, coffee, cocoa, etc.; and *condiments* — mustard, pepper, ginger, and other spices, and a variety of other *flavors* added, not for their food value (though of that they may have a small amount), but to give

a pleasant taste which may assist digestion, and to stimulate the secretion of digestive juices. Used to excess, however, all these drinks injuriously affect the nerves, and the condiments may irritate the sensitive lining membrane of the alimentary canal, besides impairing the delicacy of the sense of taste.

296. Food Values. — The nutritive value of a diet lies chiefly in the amount of nitrogen and carbon derived from it. A man of moderately active life will give off, mainly from the lungs as carbon dioxide, from eight to nine ounces of carbon each day. If he is engaged in severe muscular effort, he will give off much more carbon. The amount of nitrogen passing from the body (chiefly as urea) during a day is from .47 to .56 ounce, and with the increase of muscular activity it does not increase to nearly so great a degree as does the carbon.

In order to repair the daily waste of the tissues, the proportions of carbon and nitrogen contained in the food should be the same as in the excretions, viz. about 16.6 to 1. While the proteids contain carbon, they contain only about 3.5 parts of carbon to 1 of nitrogen, hence other groups of food elements must be depended upon to supply the necessary carbon.

The oxygen contained in food, being already combined with other elements, cannot be used in oxidation, so that from the lungs alone comes the needful supply of that gas.

Since the slow combustion within the body sets free the same amount of energy as does the rapid combustion of the same substances, by burning a quantity of food equal to that which a man eats in a day and measuring the heat given off, the amount of energy which that food can supply may be estimated. In that way it has been shown

that the energy from the fats is about equal to that from proteids and carbohydrates together. It has been estimated by a high authority that a healthful diet contains from three and a half to four and a half times as much of nonnitrogenous as of the nitrogenous foods.

297. The following table, from Landois and Stirling's Physiology, gives approximately the relative amounts of nitrogenous and nonnitrogenous elements in common articles of food, and shows that, next to human milk, wheat flour has most nearly the right proportion of the two elements. Beef and other kinds of flesh have too much proteid and should be eaten with potatoes or rice, which supply the nonnitrogenous matter needed to make the food complete. Vegetables contain too little nitrogen to be used alone as food.

	Nitrogenous		Nonnitrogenous
Veal	10	to	1
Rabbit's flesh	10	to	2
Beef	10	to	17
Beans	10	to	22
Peas	10	to	23
Mutton	10	to	27
Pork	10	to	30
Cow's milk	10	to	30
Human milk	10	to	37
Wheat flour	10	to	46
Oatmeal	10	to	50
Rye meal	10	to	57
Barley	10	to	57
Potatoes	10	to	115
Rice	10	to	123
Buckwheat	10	to	130

298. Variation in the Amount of Food Required. — When the body is at rest the amount of waste is much less than it is when the muscles are engaged in active labor. Then

the muscular tissue is rapidly broken down under the strong contraction constantly called for, and the circulation becomes swifter to supply material to rebuild the decomposed cells. Respiration, too, must be quickened to furnish a sufficient quantity of oxygen to arterialize the blood flowing faster to the lungs, loaded with the products of chemical changes in the tissue cells. Nervous tissue also is worn away by the constant demands upon it for conveying impulses to the many muscles engaged and in coördinating all their related actions.

If the body is exposed to a low temperature, a still larger demand is made for food to supply the greater loss of heat. During the period of growth a quantity of food is needed in excess of the waste products to furnish material for enlarging and strengthening all parts of the body.

299. Undigested Food. — Some (an average of about one tenth) of the food taken into the stomach, and especially a part of our vegetable food, seems to play no part in supplying nutrient material, but passes through the alimentary canal to be expelled from the body unchanged. It serves, however, as an aid to digestion by giving an increase of bulk to the food, and so assists the action of the digestive organs.

300. Cooking is the application of heat in one way or another to articles used as food. Most of our diet comes to the table after being submitted to this process, which renders it more wholesome and more palatable. By cooking, which lessens the cohesion of particles, the amount of work required of the digestive organs is reduced, and the chemical effects of heat prepare the various elements in the food to receive more readily the action of the digestive juices. Cooking also develops, especially in animal

foods, the agreeable flavors which stimulate not only the appetite, but also the secretion of the digestive juices.

Another very important effect of the application of heat in the cooking of food is the destruction of many of the germs of disease which are sometimes introduced into the human system with food. Certain diseases of animals whose flesh is eaten by man may thus be communicated to him if the meat is not first thoroughly cooked. Disease is often conveyed also by means of the water supplied to a town or a dwelling, and in all cases where there is reason for suspicion respecting the purity of the water used for drinking, it should be boiled for at least half an hour before using. This sterilizes it. Ice should never be mixed with drinking water, on account of its impurities. Sterilized water may be cooled for drinking purposes by inclosing it in tight cans of glass or metal and placing the cans in contact with the ice.

Much of our food comes to the table badly prepared, cooked too much or too little, or in an unhealthful manner. The importance of *good* cooking cannot be overestimated; the lack of it is a fruitful source of the widely prevalent disease, dyspepsia, from which result innumerable physical and mental ills. In recent years much attention has been paid to scientific cookery, and it is now taught in many schools. Only a few hints can be given here.

301. Cooking of Meats. — Fresh meat which is to be *boiled* should be put at first into water which is already boiling briskly. After fifteen minutes the kettle should be placed where, for the rest of the time, the water will only bubble slightly. By applying strong heat at first, the albumin of the surface of the meat is hardened and forms a close *coating* which retains the nutritive juices within.

When *soup* or *broth* is to be made, this process is reversed — the object being to extract the soluble portion of the meat from the fiber. The meat is cut into small pieces and the bones are cracked. All is then placed in cold water without salt, and heated slowly to a temperature just below the boiling point. It should be kept as hot as possible, without actually boiling, for from six to eight hours.

Salt meat may be placed in cold water and gradually heated. Corned beef requires boiling for about five hours.

Roasting and baking are done before an open fire or in an oven. The meat should first be browned by exposure to a very high temperature, in order to preserve the juices, and the heat should then be reduced.

In *broiling* and *frying* the same principle applies. Frying is regarded as the least healthful of the various ways of preparing food, because the fat which coats the surface is supposed to be indigestible. Anything cooked by frying should be quickly and wholly immersed in fat so hot that the surface browns at once and further absorption of fat is prevented. Then the heat should be lowered.

By *stewing* and *braising*, meats may be economically cooked at a moderate temperature, but the process requires several hours. In stewing, the temperature should not quite reach the boiling point. In braising, which is done in a closely covered pan in an oven, a higher degree of heat is applied. By these two methods the tougher and cheaper cuts of meat may be made entirely tender, nutritious, and appetizing.

302. Fish. — Principles similar to those suggested above apply to the cooking of fish.

303. Eggs. — Eggs are made most digestible by placing them (in their shells) in cool water, applying heat, and removing them from the water as soon as it boils. Or, they may be put into water already boiling, the vessel being covered and at once removed to where the water will keep warm but will not boil. They will be "done" in from ten to fifteen minutes, according to the weather and the amount of water used. In eggs cooked in this way, the albumen, which by boiling becomes hard and difficult of digestion, remains soft, creamy, and nutritious, while the yolk is partly solidified and rendered more palatable.

304. Cooking of Vegetables. — Fresh vegetables should be placed in boiling water only long enough to soften the fiber and cause the starch granules to burst. Too much cooking injures them.

Dried seeds require longer boiling, and it is often well to soak them in water for several hours before cooking.

305. Bread is our most valuable food. It is made from the various grains, also from the flour of certain nuts and rootstocks. Salt, water, and yeast, in proper proportions, and sometimes a small quantity of sugar to hasten fermentation, are added to the flour or meal, and the mass is allowed to become "light" by the fermentation of the yeast before baking. Numerous chemical changes take place in the process. The water dissolves the gluten and sugar of the flour and swells the starch granules. If the dough is at a temperature of 100° F., fermentation at once sets in; some of the starch becomes sugar; sugar is converted into alcohol and carbonic acid; the gas formed expands in little bubbles, which are surrounded by walls of sticky gluten, and "raises" the bread. If the fermentation is allowed to continue too long, a new chemical

product, called acetic acid, appears, rendering the bread sour and unwholesome.

A few things are indispensable to the making of good bread. A good quality of flour must be used and good yeast (Miss Parloa considers the "compressed yeast" sold in the shops and bakeries the best procurable). The dough should have at first a temperature of 100° F., which should later be reduced to 70°. The mass must be kneaded sufficiently to distribute the yeast evenly throughout, and again after it has "risen" to break the bubbles of gas and force it to permeate every part, that the loaf may be rendered light and spongy by innumerable fine pores. After the final kneading and shaping into loaves, they should be left to rise to about twice their original size before baking. The oven should be heated to about 400°, but for the last half of the baking the temperature should be reduced to 300°. In baking, the process of fermentation is checked as soon as the loaf is raised to a temperature of 212°. The alcohol is vaporized and driven off, the starch granules burst, and by the transformation of starch into sugar and dextrine the delightful sweetness of good wheat bread is developed. Very large loaves are undesirable, as acetic acid may be formed in their interior after they are placed in the oven. Small loaves are better than large ones, also because they have a larger proportion of crust, which is the sweetest and most wholesome part of the loaf.

Bread made of whole-wheat flour is especially valuable for children, because it contains more of the elements which are needed for making teeth and bone than does white flour. The same is true of what is called Graham flour, but the coarse bran which such flour contains is to some persons unwholesome.

Experiments

Food Elements. — Some very interesting and easily performed experiments may be made upon substances common in ordinary food.

91. *Tests for Proteids.* — To one fourth of a test tube of dilute white of egg[1] (a proteid) add a few drops of strong nitric acid and boil. Cool and add a little ammonia; the yellow color changes to orange. To show that the orange color is due to the presence of a proteid, repeat the experiment, using pure water instead of white of egg. Another test is as follows: To one fourth of a test tube of a 15 per cent solution of caustic soda add two or three drops of a 1 per cent solution of copper sulphate. Shake the mixture, and after warming add a little white of egg or other solution of proteid; the blue color becomes violet. To show that these color changes are tests for proteids, repeat the above experiments, using a solution of sugar and the starch solution mentioned below, instead of the white of egg.

92. *Coagulation of Albumin by Heat.* — Boil dilute white of egg in a test tube; it does not clot. Then add, drop by drop, dilute acetic acid (2 per cent); a precipitate of coagulated albumin finally separates. If the white of egg is not diluted, it coagulates, of course, on boiling.

93. *Solubility of Starch.* — Stir some starch into cold water and observe that it does not dissolve. Boil the mixture; solution occurs, but the liquid remains somewhat cloudy.

94. *Test for Starch.* — To some of the starch solution prepared above, add a drop of iodine solution. The blue color resulting is the characteristic reaction of iodine with starch. Dilute the starch solution and repeat the experiment. The dilution may be much prolonged before the blue color fails to appear on adding iodine. To show that the blue color is related to the presence of starch, add iodine to pure water or any liquid from which starch is known to be absent.

95. *Microscopical Examination of Starch.* — Scrape the fresh cut surface of a potato, and mount in water on a slide some of the material thus obtained. Examine with the compound microscope. Numerous

[1] To prepare dilute white of egg, beat up the white of an egg with about twenty volumes of water, filter through muslin, and pour off gently to remove air bubbles present.

small *starch granules* will be seen. Each granule shows concentric markings. Add iodine solution; the granules turn blue or blue black. Examine other kinds of starch granules, of corn, oats, rice, etc.

96. *Test for Sugar.* — To one fourth test tube of a weak solution of glucose, add an equal amount of a 15 per cent solution of caustic soda. Shake, and after adding a few drops of a 1 per cent solution of copper sulphate, boil for a few minutes. The liquid changes from blue to yellow, or, if much sugar is present, to brown in color, and a precipitate is formed. To show that the change in color is due to the sugar present, repeat the preceding, using pure water, or any solution known not to contain sugar, instead of the sugar solution. This test is known as Trommer's test. It is not a test for cane sugar, nor does it distinguish between glucose, malt sugar, and milk sugar.

97. *Fats.* — Put some melted butter, or olive oil, into a test tube one fourth full of water. The fat rises to the top. Shake well; a whitish mixture, or emulsion, is the result, but the oil and water quickly separate. To the contents of the test tube, add an equal amount of 1 per cent solution of carbonate of soda (an alkali), and shake. The emulsion with the alkali lasts much longer than that with water alone. Add a drop or two of oleic acid (a fatty acid) to the mixture, and shake well; the emulsion lasts longer than before. It will be learned later that the fats are only slightly dissolved in digestion, but are chiefly emulsified.

98. Examine with the microscope some of the emulsion prepared above. The fat will be found to be broken up into innumerable fine particles.

99. Shake some olive oil with dilute white of egg in a test tube; an emulsion results.

100. To one fourth test tube of water, add a few drops of oleic acid, and shake. The oil rises to the surface as in the preceding experiments. To the contents of the test tube add carbonate of soda as before. A white precipitate of soap is formed. An alkali and a fatty acid form soap.

During digestion some of the fat is broken down into glycerin and fatty acids. The latter unite with alkalis in the intestine to form soluble soap.

101. *Flour.* — Boil a little flour in water and test with iodine for starch.

102. Place a little flour in from five to ten times its bulk of water

in a flask and allow it to stand several hours, shaking it occasionally. Filter and test the filtrate for proteids, as in Ex. 91, and for sugar as in Ex. 96.

103. Shake some flour with ether in a test tube and allow it to stand for an hour or two, keeping the tube tightly corked and shaking it occasionally. Filter off the ether and place some of it on a clean glass surface and allow it to evaporate. A greasy residue remains, showing that the flour contained fat, some of which was dissolved out by the ether.

104. *Gluten.* — Moisten flour with water till it forms a tenacious dough. Tie it in muslin cloth and knead it in a vessel of water till all the starch is separated. There remains in the cloth a sticky, elastic mass of gluten, consisting of the insoluble albumins, some of the ash, and the fats. Draw out some of the gluten into threads, and notice its tenacity.

105. *Milk.* — Examine with the microscope a drop of fresh milk. It is seen to be an emulsion of oil globules floating in a liquid.

106. Warm some milk in a flask, and add a few drops of acetic acid. The mass clots and separates into a solid *curd*, consisting of casein and fat, and a liquid, the whey. Caseinogen is the chief proteid of milk. In curdling it is changed to casein.

107. Dilute milk with ten times its volume of water and slowly add dilute acetic acid. As long as the liquid remains alkaline, or neutral, — as can be tested with litmus paper, — no visible change occurs, but on adding more and more of the acid there is finally formed a precipitate of casein which, as in the preceding experiments, carries with it most of the fat.

108. Filter the curd from the whey obtained in one of the preceding experiments, and test the filtrate for sugar (milk sugar) and proteids (see Exs. 96 and 91).

109. Test, with litmus paper, some perfectly fresh milk. It will be found to be neutral, or alkaline. Allow it to stand in a warm place till it becomes sour and curdles. It will be found to be acid in reaction. In the souring of milk the milk sugar changes to lactic acid, and curdling is finally produced by the acid, as was illustrated in preceding experiments.

110. *Lean Meat.* — Mince finely some perfectly fresh muscles of a cat, dog, or rabbit. Place them in a large jar of water and stir. In about a quarter of an hour filter through muslin and place the muscle

in a fresh jar of water. Test the filtrate for proteids (serum albumin) as in Ex. 91. Repeat the washing till the filtrate gives no test of proteids. An hour or two of washing will suffice. Then squeeze out the water from the minced muscle, grind up the latter with clean sand, and add ten times its volume of a 10 per cent solution of common salt. Stir occasionally, and after an hour or more filter through muslin. Add some of the filtrate, drop by drop, to a large vessel of pure water; there is formed a milky precipitate of *myosin*, the chief proteid of muscle. In the living muscle the myosin exists as the soluble myosinogen. Thus in muscle there are seen to be two kinds of proteids: one, serum albumin, soluble in water, the other, myosin, insoluble in water, but soluble in weak salt solution.

CHAPTER XVII

THE DIGESTIVE APPARATUS AND NUTRITION

306. The apparatus for digestion consists of the *alimentary canal* with its appendages. This is a long, irregular tube having a continuous lining of mucous membrane. It comprises the *mouth*, *pharynx*, *esophagus*, *stomach*, and *large and small intestines*. Numerous glands along its length furnish the *digestive juices*.

307. The Mouth (Fig. 108) is the chamber which receives the food through the opening and closing *lips*. The *soft palate* at the back forms a curtain over the opening at the back, while the *hard palate* of the roof, the soft muscular walls of the *cheeks*, and the large muscle of the *tongue*, together with the *teeth*, all assist in the process of *mastication* to which the food is first subjected. As in the skin, many minute *papillæ* are found in the mucous membrane, containing networks of nerves and blood vessels. Some of these contain *taste corpuscles*. Some have *organs for touch*.

308. The Teeth are the special organs for cutting and grinding the food. Two sets of teeth are provided. The first, which appear in infancy and are only twenty in number, are called *temporary* or *milk teeth*. They fall out after a few years, to be replaced by the *permanent teeth*, thirty-two in number.

The four front teeth on each jaw are called *incisors*.

Next to them come the *canines*, one on each side, then the two *bicuspids*, or *premolars*, and next to them three *molars* on each side. The third pair of molars on each jaw are called the *wisdom teeth*, and they sometimes fail to appear.

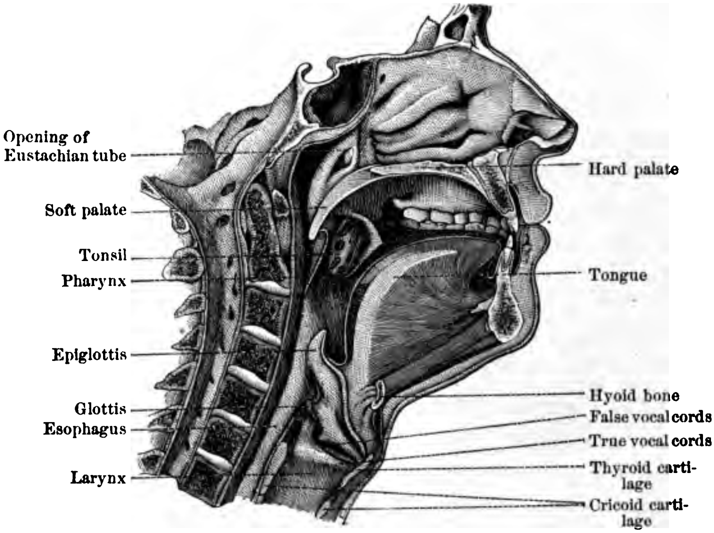


Fig. 108.—Vertical section of the head and neck.

The teeth of different animals are adapted in form and structure to the food upon which they subsist. Carnivorous animals are provided with strong, sharp teeth for seizing and tearing flesh, while the teeth of herbivorous animals are broader and relatively shorter, with wide-ridged surfaces for grinding grains and plant fiber. Man, as requiring both animal and vegetable food, is provided with teeth of both sorts.

309. Structure of a Tooth (Fig. 109).—A tooth has three parts,— *crown*, *neck*, and *roots*. The *crown* is the part which projects beyond the gum, and is covered with the firm,

solid layer of *enamel*, the hardest tissue found in the body. The *neck* is the narrowed portion just below the crown, surrounded by the gum. The *root* (one or more) is the remainder of the tooth, which is secured to the socket of the jaw by means of the periosteum, through which it derives nourishment. A tooth is composed of a hard, close material called *dentine*, much like bone, but with less animal matter. This is molded round the central *pulp cavity*, which contains the *tooth pulp* — a mass of loose connective tissue, blood vessels, nerves, and cells of different shapes, one sort of which builds the dentine. A layer of true bone, called *tooth cement*, surrounds the dentine of that part of a tooth embedded in the gum, as enamel caps the crown.

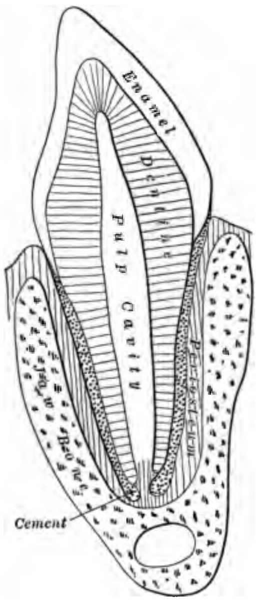


Fig. 109. — Diagram of the structure of a tooth.

310. The Tonsils. — Between the arches of the soft palate lies on each side a soft rounded body covered with mucous membrane and containing many small glands which secrete mucus. They are called the *tonsils* (Fig. 108). Their use is unknown except that they furnish some protection to the larynx and pharynx. Being sometimes permanently enlarged and subject to frequent inflammation, they are occasionally removed by the surgeon with apparent advantage to the patient.

311. The Pharynx (Fig. 108) lies behind the soft palate.

It has muscular walls, mostly of voluntary fibers, which contract upon the food to push it into the esophagus, or may force it back into the mouth if desired. Seven passages open into this cavity: the *mouth*, the two *nasal passages*, the two *Eustachian tubes*, the *larynx*, and the *esophagus*.

312. The Esophagus connects the pharynx with the stomach (Figs. 108 and 110). It is a muscular tube lying along the spinal column behind the trachea. The muscular coat of the wall of the esophagus contains an external layer of fibers running lengthwise, while the second layer is of circular fibers. They are mainly involuntary and supplied by the vagus nerve, with fibers from sympathetic ganglia also.

313. The Stomach lies in the cavity of the abdomen immediately below the diaphragm (Fig. 86, p. 153). It is a large sac, formed by the dilation of the alimentary canal (Fig. 110), and its walls have the three coats of the rest of that canal, — the inner *mucous coat*, the middle *connective tissue coat*, and the external *muscular coat*, with a fourth coat in addition, the *peritoneum*, which forms the lining of the abdominal cavity and is reflected back over the organs (or most of them) which it contains. The peritoneum adheres to the walls of the abdominal cavity, folds of it surround the blood vessels running to the stomach, and a large pouch of the same forms a sling for the stomach. From the lower side of the stomach another large fold of the peritoneum, called the *great omentum*, spreads over the rest of the abdomen. After middle life it often holds a large accumulation of fat.

The muscular coat of the stomach is composed of layers of unstriped muscular fibers. Its mucous lining is inelastic, and as it lines the organ smoothly when it is distended,

it must lie in folds when the stomach is empty and shrunken (Fig. 110). The blood supply of this membrane is very large during digestion, and its appearance is then much redder than at other times. The two open-

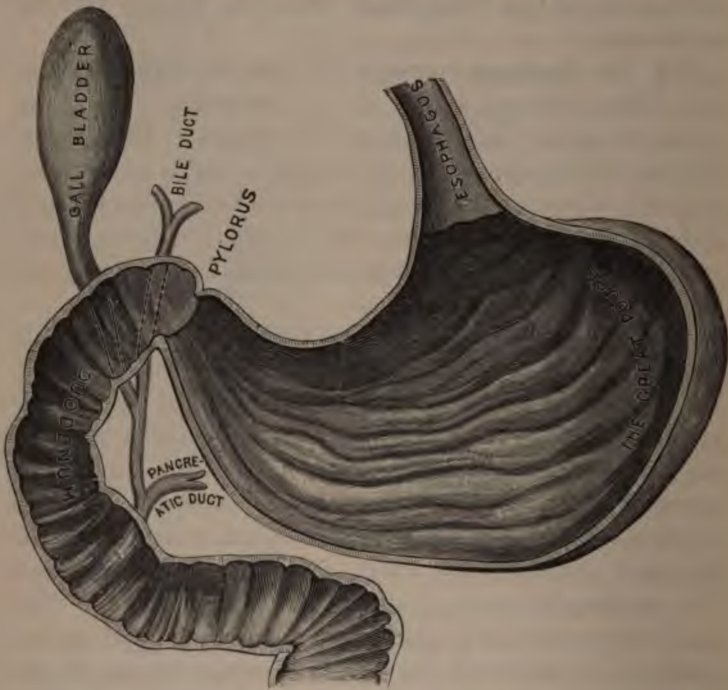


Fig. 110. — Stomach and duodenum.

The anterior walls are cut away to show the folds of the mucous membrane, rugæ of stomach, and valvulæ conniventes of intestine.

ings of the stomach are both upon the upper side. That near the left end, the *cardiac orifice*, admits the food from the esophagus; that on the right, the *pyloric orifice*, connects with the small intestine. The latter is surrounded

by a thick ring of circular muscular fiber, forming a *sphincter muscle*, which keeps the opening closed except when food is ready to pass from the stomach.

314. Nervous Supply of the Stomach. —Nerve fibers from many centers reach the different coats, glands, and blood vessels of the stomach and those of the large and small intestines. They are gathered in large tangles of nervous matter, called *plexuses*, which contain branches from the vagus nerves, from many of the spinal nerves, and from the ganglia of the sympathetic chain. The *great solar plexus*, or *epigastric plexus*, is placed at the pit of the stomach (Fig. 22, p. 31); the *hypogastric plexus* lies before the last of the lumbar vertebræ, and divides into two parts, one lying on each side of the rectum. These plexuses give rise to innumerable branches which control the complicated processes of digestion, the precise path of each different sort of nervous influence not having been yet made out. It is easy to see, however, that this close nervous connection of the digestive organs with all parts of the system implies important relations between them.

Vagus nerve fibers appear to stimulate the peristaltic or wavelike movement of the stomach and bowels, which by the progressive narrowing of the tube forces on its contents, while the sympathetic fibers are inhibitory and bring the movements to an end. It is believed that the walls of these organs possess some power of spontaneous action such as appears in the walls of the heart.

315. The Small Intestine (Fig. 111) is a tube with many curves, about twenty feet in length, two inches in diameter at its upper end and somewhat smaller in its lower portion. Its coats are the same as those of the stomach, but the peritoneum, a fold of which forms the outer coat, does not entirely surround the tube, but runs off to form a sup-

porting membrane for the intestine, called the *mesentery*. This is gathered up and connected with the wall of the abdominal cavity near the spinal column. The blood vessels and nerves pass through the mesentery to reach the intestine, and the *absorbents* also pass through it from the intestine. The two layers of muscular fibers, one circular and one longitudinal, in the intestinal wall, are of the unstriped, involuntary kind.

Fig. 111. — **The stomach and intestines.**

1 stomach.
2 duodenum.
3 small intestine.
4 termination of the ileum.
5 cæcum.
6 vermiform appendix.
7 ascending colon.
8 transverse colon.
9 descending colon.
10 sigmoid flexure of the colon.
11 rectum.
12 spleen.
13 anus.

316. Nerves of the Small Intestine. — Between the muscular layers is a plexus of nerve fibers with many ganglia, and in the layer beneath the mucous membrane of the lining is another nerve plexus, also gangliated.

317. The Mucous Membrane of the Small Intestine has a very important part in the function of digestion, and is of peculiar structure. Like the lining membrane of the stomach, it has an inner layer of columnar epithelium, but unlike that of the stomach the lining of the intestine is for a large part of its length laid in folds which do not disappear when the canal is distended. These folds are called *valvulæ conniventes* (*Fig. 110*). They lie around the inner surface of the

intestine, each separate valvula reaching about one half or two thirds the way round. Their function is to furnish a large amount of secreting and absorbing surface.

318. The Villi. — Still further to increase this surface, the valvulæ are covered with *villi*. These are minute projections from one fiftieth to one eighth of an inch

Fig. 112. — Diagrammatic representation of a small area of the mucous membrane of the small intestine.

1 cellular structure of the epithelium, or outer layer.
2 a vein.
3 fibrous layer.
4 villi covered with epithelium.
5 a villus in section, showing its covering of epithelium, and its blood vessels and lymphatics.
6 a villus partly uncovered.
7 a villus stripped of its epithelium.
8 lymphatics or lacteals.
9 orifices of the glands opening between the villi.
10, 11, 12 glands.
13 capillaries surrounding the orifice of a gland.

in length, and are found only in the small intestine (Fig. 112). They give to its mucous lining a peculiar velvety appearance. Each *villus* is covered with columnar epithelium resting on a fine membrane. Within are blood vessels

(two or more arteries, a dense network of capillaries, and one or two veins), connective tissue fibers, and a single lymphatic or lacteal vessel, which may be looped or branched (Fig. 113). Between blood vessels and lymphatics is a very thin layer of fine muscular fibers, which help to propel the chyle along the lacteals. Fine nerve fibers are also found. In the villi the digested food passes through the cells of the thin wall into blood vessels and lacteals.

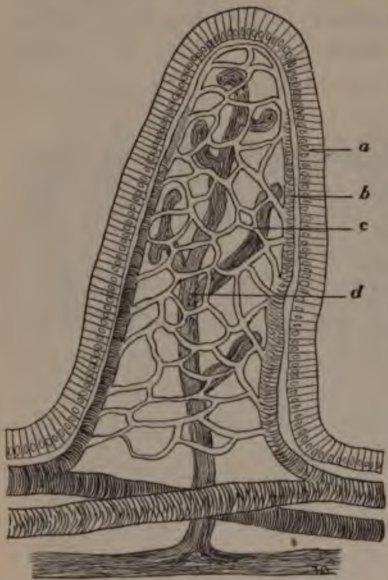


Fig. 113. — Diagram of the essential parts of a villus.

a epithelium which takes up food and transports it to the tubes within.
b an artery. *c* capillaries. *d* a lacteal.

319. The Large Intestine (Fig. 111). — The small intestine passes into the *large intestine*, the *ileo-cæcal valve* at the junction preventing any reflux of the contents from the large to the small tube. The large intestine has three parts, called the *cæcum*, the *colon*, and the *rectum*. The *cæcum* is a large sac on the right side, which receives the contents of the small intestine. Attached to the lower side of the cæcum is the small *vermiform appendix*, which has no known function, but is regarded as a "survival" from a previous type of animal structure. Continuous with the cæcum is the *colon*, having *ascending*, *transverse*, and

descending parts. The *rectum* is the final portion of the alimentary canal; it opens externally at the *anus*.

The walls of the large intestine are like those of the small intestine, except that the valvulæ conniventes and the villi are wanting. In the cæcum and colon the longitudinal muscular fibers are for the most part collected in three bands, which, being shorter, from end to end, than the other coats, draw up the intestinal wall into puckers, or folds.

The muscular coat of the rectum is much thicker than elsewhere, and at the anus is a strong band called the internal sphincter muscle.

320. Secretion. — All the living cells of the body are engaged in taking from the blood certain substances suitable for their own special purposes, and returning to the blood those particles of matter which have fulfilled their mission and are no longer of use. Every cell requires oxygen, and oxidation is now understood to occur within all the cells. But certain cells or groups of cells take up also other substances from the blood, and manufacture within themselves a new product having a special function. This process is called *secretion*, and the organs of secretion are called *glands*.

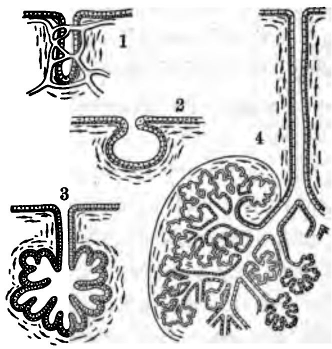


Fig. 114. — Structure of glands. 1 simple pit, surrounded by capillaries. 2 flask-shaped gland, with short duct. 3, 4 more complex glands, with longer ducts.

321. Glands. — The simplest glands are merely minute tubes lined with cubical cells (Fig. 114). Sometimes these tubes branch at the inner end, all the branches being lined with the secret-

ing cells, and all uniting in a single tube, or *duct*, through which the secretions pass. Frequently a large number of branches from a secreting tube are grouped together in clusters to form an organ of considerable size, as the liver or the pancreas.

The secreting surface is always composed of living cells, and the processes carried on in them are similar to those occurring in other cells. That is, secretion involves building up, or growth, and breaking down, or waste, of the cell substance, along with other changes. Under the microscope the cells of the glands are seen to contain a nucleus and many granules. These granules are products of the cell itself. When the secreting process is going on, water and other substances pass through the cells from the blood, and at the same time the granules are dissolved in the water and pass out along the secretory duct. Secretion is a manufacturing process, and not merely a filtering out of certain substances from the blood. In each gland the chief or specific constituents of its peculiar *juice* are formed in the cell and not simply extracted from the blood.

The mucous membrane of the whole of the alimentary canal is largely made up of glands.

322. Salivary Glands (Fig. 115). — There are three pairs of *salivary glands*. Those lying in front of each ear are the *parotid glands;* those under the lower jaw on each side, the *submaxillary glands;* and those under the tongue, the *sublingual glands*. They are large glands whose ducts pour their watery secretions into the mouth.

323. Nervous Action upon the Salivary Glands. — Ordinarily the nervous action affecting the salivary glands is reflex. The organs of taste are stimulated by food, or *the sight or* odor of food stimulates the optic or olfactory

nerves, the nervous center in the brain sends impulses to the special center in the medulla oblongata from which efferent secretory impulses are reflected, and they pass along the fibers of a branch of the seventh cranial nerve, which probably contains fibers from the ninth nerve, with which it communicates. The impulse finally reaches the cells of the submaxillary and sublingual glands, and a flow of saliva results. Even the thought of food, by stimulating a center in the brain, may produce nervous impulses having the same effect. Nerve branches from the sympathetic system also carry stimulus to these glands.

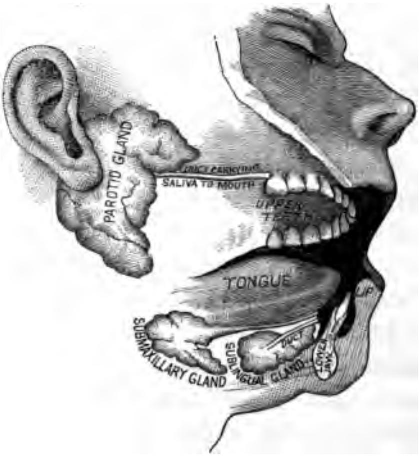


Fig. 115. — The salivary glands of the right side.

For the parotid glands the chief secretory nerve fibers arise in the glossopharyngeal nerves (ninth cranial).

324. Action of Saliva. — A part of the digestion of food takes place in the mouth. Saliva is mixed with the food by mastication, and serves to moisten the mass and lubricate it for swallowing. It also causes a chemical action, due to the presence of its active principle, *ptyalin*, which affects the starch in food, converting it into malt sugar. If one chews slowly a few grains of wheat, he will notice that the paste becomes sweet. This is because some of the starch in the wheat is changed by the saliva into sugar.

325. Ferments. — The ptyalin belongs to a kind of substances called *ferments*. Of these there are two classes, — the organized and the unorganized. The organized ferments are living vegetable organisms. *Yeast* is one of them, the *vinegar plant* is another, and the various kinds of *bacteria*, some of which cause disease, are other examples. The *unorganized ferments* are chemical substances resulting from the activity of living cells, and capable of effecting certain changes in particular substances. The ptyalin is one of these. The ferments are the agents for effecting most of the changes which the food undergoes in digestion.

326. Gastric Juice. — The epithelium of the lining of the stomach consists of a single layer of cells, and the mucous membrane is almost entirely composed of simple tubelike glands closely packed together. When food reaches the stomach, more blood is sent into the dilated blood vessels, and the glands make from the blood a colorless fluid called *gastric juice*, which flows into the cavity of the stomach.

Chemical analysis shows that gastric juice contains, besides *water*, a small amount of *salts*, a little free *hydrochloric acid*, and two of the ferments, called *pepsin* and *rennin*. *Rennin* is that element in the gastric juice which causes milk to curdle. The use of rennet (which is obtained from the stomach of a calf) in the making of cheese depends upon the presence of this ferment. *Pepsin* is the ferment which is able to change proteids into soluble form, and to make diffusible such as are not already so. The ferments of the gastric juice act only in the presence of an acid, and to assist their action seems to be the function of the *hydrochloric acid*.

327. The Food in the Stomach. — The effect of the gastric *juice upon* the food in the stomach is to make the whole

mass acid. This destroys the ptyalin, and no more starch is converted into sugar. As the saliva acts only upon starch, so the gastric juice acts only upon the proteids. By the muscular movements in the walls of the stomach the food is moved from side to side and thoroughly mixed with the gastric juice, and the mass becomes semifluid. The fats and carbohydrates remain unchanged, except as affected by the warmth of the stomach and by the removal of the proteids which are dissolved out of the mass.

328. Digestion in the Small Intestine. — The food by remaining in the stomach from one hour to three or four, is converted into what is called *chyme*. The sphincter muscle of the pyloric orifice relaxes at intervals, and the chyme is then passed on into the small intestine by the contractions of the wall of the stomach. Here it soon encounters two other juices, the *bile* and the *pancreatic juice*, by which it is still further changed.

329. The Pancreas is a long, slender gland, enlarged at its right end, lying back of the stomach and along its greater curvature, and supported by the mesentery (Fig. 94, p. 163). It is pinkish yellow in color, and resembles the salivary glands in structure. A duct runs from one end to the other, joins the common bile duct from the liver, and passes with it obliquely through the wall of the small intestine (Fig. 110).

330. The Pancreatic Juice. — The pancreas has reflex nervous connection with the stomach, and as soon as food enters the latter, secretion begins in the pancreas, and the secreted fluid accumulates in the small intestine.

The *pancreatic juice* is a clear, somewhat viscid, alkaline fluid, containing many different substances, the most important being the ferments. Of these there are four.

One, similar to pepsin, but able to act only in an

alkaline medium, affects the proteids more rapidly and more powerfully than pepsin, and so digests those which were not sufficiently changed by the gastric juice.

Another ferment in the pancreatic juice acts like the saliva upon starch, converting it into malt sugar, but its action is far more powerful. This ferment is not present in the pancreatic juice of infants, and they are therefore unable to digest starchy foods properly.

The pancreatic juice has two different effects upon the fats, they having hitherto been unchanged. The first effect is to separate them into exceedingly small particles, which can pass through the walls of the intestine, that is, the juice forms an *emulsion* with the fat. The second effect is a chemical decomposition of fat into *fatty acid* and *glycerin* by the action of the third of the pancreatic ferments. The acids set free unite with the alkaline substances present to form *soaps*.

The fourth ferment possesses the power of curdling milk, as does rennin, though its action is not identical with that of rennin. It is able to act upon any particles of milk which have by any possibility escaped the influence of the gastric juice.

331. The Secretory Nerves of the Pancreas have been found to be fibers of the vagus, or tenth cranial nerve, which, as already mentioned, are stimulated by efferent impulses excited in the brain by afferent impulses from the stomach.

332. Other Functions of the Pancreas. — In addition to its office in connection with digestion, experiments have proved that this gland has some further influence upon the general condition of the body; but what that influence is, is as yet unknown.

333. The Liver, which weighs from fifty to sixty-four ounces, is the largest gland in the body. It lies chiefly

on the right side, immediately under the arch of the diaphragm (Fig. 86, p. 153). The peritoneum, without entirely covering it, adheres closely to it and attaches it to the diaphragm and other parts. By a deep fissure it is separated into right and left lobes (Fig. 116). The tissue elements of the liver are the *hepatic cells*, and all the other parts contribute to their support, protection,

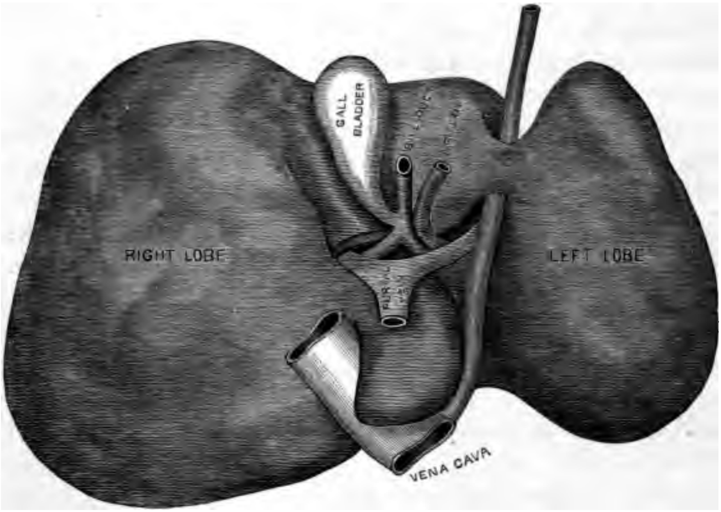


Fig. 116. — The liver seen from below.

and nutrition. The hepatic cells are grouped together in little masses to form *lobules*, which are permeated by the blood capillaries from the portal vein and the hepatic artery. From these capillaries the blood passes to a small vein which unites with those from other lobules to form the *hepatic veins*, which empty into the inferior vena cava.

334. Blood Supply of the Liver. — The liver has an immense supply of blood. That which is brought by the

portal vein has first circulated through the stomach, the spleen, and the intestines (Fig. 95, p. 165), and has been deprived of most of its oxygen. The supply of arterial blood through the *hepatic artery* is relatively small.

335. Functions of the Liver. — One of the functions of the liver is to store up sugar, or, rather, to form from the sugar brought by the portal vein a substance called *glycogen*, which is readily converted again into sugar. The protoplasm of the hepatic cells possesses the power of manufacturing glycogen from carbohydrates and of storing it up. This is effected by means of a ferment found in the liver; but what is the part played by glycogen in the animal economy is not fully determined. Glycogen is turned into sugar again and supplied by the liver to the blood as it is needed. There is always sugar in the blood, but more than a small amount seems undesirable. There is much evidence that another function of the liver is to act upon the nitrogenous foods in some manner resulting in the production of the waste substance, *urea*, which is eliminated by means of the kidneys. A third and the most familiar office of the liver is the formation of *bile*. This is stored in the *gall bladder*, lying between the two lobes on the under side of the gland (Fig. 116). Still another function of the liver is to protect the system from the action of poisons produced by the processes of digestion or by defective digestion. These are arrested or transformed when they reach the liver.

336. The Bile is secreted from the portal blood as a yellowish, reddish brown, or green fluid, according to the preponderance of different coloring matters which are formed by the liver out of the hemoglobin of the red blood corpuscles. It is alkaline and is thought to have antiseptic properties. Bile is a poison, and in one person enough is

secreted in a day to kill three men ; but it is neutralized in the intestines, in the liver, in the tissues, and in the blood. Upon the food with which it mixes in the small intestine bile seems to have little effect, and its function there is supposed to be mainly to assist the pancreatic juice in neutralizing the acid in the chyme, and in its further action. Secretion of the bile goes on continually, but it passes into the intestine only when digestion is proceeding. At other times it is carried by a side branch of the bile duct to the gall bladder and there stored. About two pints of bile is secreted daily.

337. The Intestinal Juice is a secretion of the mucous membrane of the small intestine itself, and contains a ferment which changes cane and malt sugars into glucose, besides having possibly further action upon the food.

338. Bacterial Action. — There have been found to exist in the alimentary canal certain microörganisms which modify the digestive processes. Bacteria are especially numerous in the intestines. The antiseptic gastric juice destroys bacteria, or neutralizes their action in the stomach; but some escape into the intestines, where they multiply. Their presence is shown to be, under normal conditions, beneficial, though certain forms of bacteria produce disease.

339. The Peristaltic Movements of the Intestines. — By successive contractions and relaxations of the muscular fibers in the two muscular layers of the intestinal wall, a wave-like motion passes along the whole length of the organ and forces the contents, from the constricted to the relaxed portion, slowly on into the large intestine, bringing the different substances in contact with the absorbing cells in the mucous membrane.

340. Function of the Large Intestine. — Most of the food which can be used in the body is absorbed in the stomach

and small intestine, so that what is left to pass into the large intestine is indigestible matter and the remains of the juices. The tubular glands in the mucous membrane here absorb what is left of nutrient material and a considerable amount of water, which is carried by the small veins to the portal vein. The residuum, becoming more solid as the water is absorbed, passes into the rectum and is discharged as *fæces*. The chief alteration in the contents of the large intestine is due to the action of micro-organisms which cause chemical changes, giving rise to organic acids.

341. Absorption. — When the food has been *digested* it is ready to be *absorbed*. It cannot be used for the support of the body until it reaches the blood, and there are two ways by which it may reach the blood. First, it may be absorbed directly into the blood. The mucous lining of the alimentary canal is richly supplied with absorbing cells. Little of the food, however, is taken up in the mouth and esophagus, because of the thickness of the epithelium in those cavities, and because the food passes quickly through them. In the stomach, and especially in the small intestine, the absorbents are very numerous, and a large amount of digested food passes directly into the blood stream by the capillaries through the columnar cells of their epithelium; while the walls of the large intestine also absorb food, but to a less extent. This direct passage into the blood is now regarded as the more important of the two channels of absorption. The living cells, while allowing water and soluble salts to pass through them unchanged, effect certain changes in the organic food materials while in contact with them. The carbohydrates and proteids are mainly absorbed into the blood in this immediate way.

342. The second agent of absorption is the *lymph cells* in the tissues of the walls of the alimentary canal. It is chiefly by the lymphatics that the fat of the food gets into the circulation. Two changes are effected in the fats by the digestive juices in the small intestine to prepare them for absorption by the lymphatic vessels, which are in the intestines called *lacteals*, because the presence of fat renders the fluid they contain milky. First, by the mixture of the bile and pancreatic juice with the food an *emulsion* is formed; that is, the fat is broken up into minute particles, which float in the liquid, giving it a milky appearance. Secondly, a chemical union takes place between some of the acid fats and the alkaline secretions of the digestive organs, — a process called *saponification*, which is the making of soap. The digested food in its milky form is called *chyle*, and this is collected in larger and larger tubes, and finally poured by the great thoracic duct into the blood of the jugular vein. Being then carried to the right auricle of the heart, it passes to the right ventricle and thence to the lungs, in whose capillaries it meets with the oxygen from the air, and having returned to the left side of the heart is distributed throughout the system.

343. **The Lymphatic Vessels** are delicate tubes which drain the spaces between the cells of the tissues, gradually uniting to form the main lymphatic vessels, of which the *thoracic duct* is the largest. These vessels are supplied with numerous valves, like those of the veins, to prevent the reflow of their contents, and the opening of the thoracic duct is guarded by a valve. The flow of the fluid is kept up by the pressure in the capillaries, which is greater than is the pressure in the veins into which it is emptied, and by the movements of the body, which

constantly cause pressure upon the tissues and so force the lymph onward in the vessels, the valves preventing any return.

344. Assimilation. — Though the food has been masticated, digested, and absorbed, it has not yet nourished the body. Still another process is needful before the new material becomes part of the continually wasting tissues. That process is called *assimilation*, and, though we cannot pretend to understand it, it may be described as the action of the living cells in choosing, appropriating, and building into their own substance the suitable elements in the food-laden fluid which comes to them from the alimentary canal and from the lungs.

Correlative to the process of assimilation is the destructive process by which the cells, by combustion and other chemical changes, break up and send out as waste the substances of their structure, to be expelled from the body as *excretions*.

345. Hunger and Thirst. — We associate our feelings of *thirst* with a dryness of the mucous membrane of the mouth and throat, and we say our throats are "parched" when we are very thirsty. But under ordinary circumstances the feeling of thirst arises from a general condition of the system, in which the throat shares, due to a lack of water in the blood, or rather in the lymph. Thirst may be temporarily relieved by moistening the mucous membrane of the soft palate. Hence follows the inference that the afferent nervous impulses originate there, and are caused by a too great removal of water from the lymph of the investing membrane.

Hunger is referred in our consciousness to the particular locality of the stomach, and that organ seems to us to be empty when we are hungry. Indigestible mate-

rial introduced into the stomach may for a time relieve the hunger, as will a very small quantity of food. The special sensation of hunger appears to be connected with the state of the lining membrane of the stomach, while it must be ascribed in a more general sense to a deficiency of nutrient matter in the blood. Hunger may be alleviated by the introduction of soluble food into the circulation, through the rectum, or through the absorbents of the skin, but the relief comes more slowly thus than through the stomach.

The nervous path of hunger sensations has not been made out. The vagus is regarded as the sensory nerve of the stomach, but it is said that both vagus nerves may be cut and the sensation of hunger be unaffected. The brain centers for thirst and hunger are believed to be in the occipital lobes of the cortex, but they have not been definitely located.

346. Some Practical Points connected with Nutrition. — In order that the first of the digestive operations may be properly performed, it is necessary to have *a good set of teeth* and to *chew thoroughly* the food taken into the mouth. The intensely hard enamel covering the exposed portion of the teeth is a full protection to them against all dangers under proper conditions of life, and under such conditions the teeth would last while life lasts. That this is true is shown by the fact that nature makes no provision for restoring or improving the enamel after it is once formed. Here alone the special cells, whose office it is to form the peculiar substance, entirely disappear when their work is once completed. In all the other tissues these formative cells remain to continue the nutrition and repair of the tissues. But the tooth enamel, whose growth, except in the wisdom teeth, is complete

when a child is ten or eleven years old, cannot be renewed or improved after that time. It is therefore of the utmost importance that young children should be fed upon food which will build up perfect teeth. Milk should be largely relied upon for the first three years, the diet to be varied during the third and after years in accordance with suggestions given in the chapter on Food. Great care should be taken to guard children against attacks of what are known as "infantile diseases," — measles, whooping cough, etc., which sometimes suddenly arrest or disturb the general nutrition, and especially that of the teeth, so that the enamel becomes rough and irregular, and the teeth are exposed to early decay. Another point should receive special attention. It is observed that young children who live a life of excessive nervous activity, with overstimulation of the brain, are particularly liable to defective development of the enamel of the teeth. This is one among many reasons which make imperative a quiet, regular life for children, without excitement and without undue mental activity.

347. But even perfect teeth may be injured by certain bacteria, which multiply in the decaying particles of food allowed to remain in the mouth. These minute organisms form a corrosive acid which destroys the enamel and breaks down the tooth substance. If the teeth are perfect and are always kept perfectly clean, they will not decay. They should be thoroughly brushed — the upper teeth downward, the lower ones upward — after each meal, and a thread of soft untwisted silk floss or fine strips of rubber should be drawn back and forth between the teeth to cleanse those parts which a brush cannot reach. In brushing the teeth a powder or liquid should be used which contains some safe germicide, — which is a substance destructive to

the microörganisms mentioned above, — and the mouth should be well rinsed with a solution of the same.

348. It is a mistake to suppose that a child should be supplied with soft, pulpy food. Just as soon as the first set of teeth are in place, he should have a fare which will require vigorous mastication. He should not be allowed to reject bread crusts and eat only the soft crumb, nor should his bread be always soaked in milk or gravy. Plenty of hard "chewing" is not only good for the teeth; it also promotes the flow of the saliva necessary to digestion and aids in the development of the jaws, and so helps to provide room for the second set.

The teeth should be under the care of a competent dentist, who by yearly or semiyearly examination and repair will be able to forestall and prevent the inroads of decay.

349. While a due action of the mechanism of mastication is to be sought, that overactivity which results from the *habit of chewing tobacco or gum* is to be avoided. While a sense of propriety and good taste should alone be sufficient to condemn such a habit, there are hygienic reasons for its avoidance. The constant stimulation of the salivary glands leads finally to their weakness and defective action, thus laying a foundation for general derangement of digestion. Many dentists also regard it as directly injurious to the teeth.

350. Food is not ready for the action of the gastric juice until it has been finely divided by the teeth and all portions well moistened with saliva. Slow and thorough *mastication* is therefore necessary to perfect digestion. Too rapid eating not only shows bad manners, but also is exceedingly bad for the health.

351. The *temperature of our food* should not be so hot as to stimulate unduly the glands of the mucous mem-

brane of mouth and stomach, nor so cold as to retard the digestive processes, which normally require a temperature of about 100° F. (38° C.). Ice water should never be drunk, both because of the impurities usually found in the ice, and because its coldness is injurious to the stomach. Very large quantities of any liquid taken with the food may dilute the gastric juice so much as to delay digestion and weaken the organs.

352. It is well to establish and adhere to *regular hours for meals.* The intervals between meals should be long enough to permit the digestive organs to rest between their periods of activity, and fresh food should not be taken into the stomach to mix with that partly digested; that is, "eating between meals" is to be avoided. A habit of continually nibbling at dainties is extremely pernicious, and may give rise to serious and perhaps incurable disease.

353. A considerable *variety in diet* is wholesome, but as a rule one should adhere to the simpler and more easily digested kinds of food. A person in health is scarcely conscious of possessing a stomach, but injudicious indulgence may so disorder the natural processes that they will be constantly attended with discomfort or suffering.

354. It is impossible to prescribe definite rules for the *quantity of food* to be taken daily. A strictly natural appetite is undoubtedly a safe guide; but appetite is so often and so early perverted that it is seldom reliable. Food enough must be taken to supply the daily waste of tissues. Continuous loss of weight is usually a seriously unfavorable symptom. During the natural period of growth the amount of food must be sufficient to supply also what is needed for the full development of the body. One living a life of physical activity requires, as a rule,

more food than one engaged in sedentary occupations. Brain workers, however, need a varied and generous diet, and along with it great care should be taken to secure sufficient outdoor exercise. More food is called for in winter than in summer, and more of the carbohydrates to supply the demand for additional heat. Those who work vigorously in the open air, and especially in cold climates, often consume prodigious quantities of fats without injury to digestion. With the coming of old age the vital processes in general are carried on more slowly; digestion and especially the power of assimilation are enfeebled. Less energy is called for as the activities are lessened, and less food is then required, with longer intervals between meals. Foods rich in proteids are less needful and should be diminished in quantity, while those which yield a large amount of heat should be substituted.

355. What is Alcohol? — All organic bodies are subject to decay; the complex compounds of which they are composed are broken up into simpler ones, and that which was living, organized matter becomes lifeless and inorganic. This destruction of organic tissue is due under ordinary circumstances to the process called *fermentation* in some one or more forms. This is the growth and rapid multiplication of minute organisms, of which yeast is the most familiar example. When the decomposition of organic matter takes place under certain conditions and reaches a certain stage, it is called *putrefaction*. This is always attended by the multiplication of the low forms of life known as bacteria, and by the production of poisonous and ill-smelling gases. Another form of fermentation is that which occurs in the juices of fruits, grains, and vegetables which contain sugar; and is called *vinous fermentation*. In this form of decomposition the

fungus known as the *yeast plant* is the active agent in producing the changes which occur. The sugar of the fruit or plant must be in solution, and the germs of the yeast must in some way be introduced.

Alcohol is one of the products of vinous fermentation. It is composed, like sugar, of carbon, hydrogen, and oxygen, but in proportions different from their proportions in sugar. The drinks which contain alcohol differ widely in flavor according to their sources, and also vary in the amount of alcohol which appears in them. In cider and some kinds of beer the proportion may be as low as 2 per cent. As alcohol is a very volatile fluid, it may be readily separated from the other substances in the fermented liquor by the process called *distillation*. This is the driving off of the alcohol in the form of vapor by the application of heat, and its recondensation, by cooling, to liquid again. In this way is obtained the strong alcohol which is mixed with various coloring and flavoring matters to form the *spirituous liquors* of commerce. Whether a drink contains the 2 per cent of alcohol found in cider, or the 50, or more, per cent found in whisky, or the 90 per cent of "cologne spirits," the alcohol is in all cases identical in its nature and properties.

356. Properties of Alcohol. — Pure spirit, or "absolute alcohol," is a colorless, volatile liquid with a strong affinity for water, which it rapidly absorbs from the atmosphere or from any other substance containing water with which it comes in contact. Alcohol burns readily in the open air, that is, it is quickly oxidized and changed in its chemical composition. It is a powerful solvent, dissolving many substances not soluble in water. Though itself the product of fermentation, it is a preventive of putrefaction, — that is, it preserves animal tissue from decay,

— and introduced in sufficient amount into a liquid in a state of vinous fermentation it destroys the power of the yeast plant to multiply, while in smaller quantities it retards the growth of the living cells in direct proportion to its amount. When by the decomposition of sugar in vinous fermentation the amount of alcohol produced has reached 14 per cent, no further growth of the yeast takes place. That proportion of alcohol destroys the vitality of the living cells. It is thus useful as an antiseptic. Brought in contact with food elements outside the body, alcohol is found to harden them by abstracting the water which they contain, and to coagulate the albumin, which is thus rendered insoluble.

357. Is Alcohol a Food? — Alcohol contributes nothing to the formation of tissue, and cannot, therefore, be classed in the first division of foods, according to the definition given in § 289. As it is now proved that when taken into the stomach in dilute form and in small quantities it may be fully oxidized, producing energy, it must be reckoned in the second class of foods, as a force generator. For its stimulating effect it must also be included among the force regulators. It acts upon the digestive glands, causing them to pour out their special products more rapidly, and so seems sometimes to assist digestion.

But, although alcoholic drinks in very small amounts are found to come, strictly speaking, under the definition of food, in that they may and do develop or regulate force, they possess at the same time properties so peculiar and so dangerous that it is wise to exclude them wholly from our dietary, and use them, if at all, only under the advice of a skillful physician in case of illness. In certain abnormal conditions of the system, when ordinary food cannot be digested, it has sometimes been found that

an alcoholic drink, not requiring digestion, will supply the necessary energy to sustain life until the diseased organs have time to regain the power to assimilate better food. But to the healthy body there is no need of such a whip and spur, and the stimulus of alcohol upon the secretions of the digestive tract, frequently applied, is likely to result in overstimulation of the organs, and consequent weakness, with a long train of evils to follow.

As a food, alcohol is of little value compared with other substances. It is more expensive than almost anything else that is ever used as food, and cannot by itself sustain life; for, while it does generate a certain amount of energy, the body is really feeding upon the stored-up proteids, and the cost of the few spoonfuls of whisky or brandy, or the quart of beer which may perhaps be drunk without immediate bad effects, would buy of wholesome bread and meat enough to produce in the body many times the amount of normal force which the alcohol imparts.

358. Alcohol as a Poison. — The beneficent use of alcoholic drink seems to be wholly confined to its application as a medicine to diseased conditions of the system, and with that sort of use we have here nothing to do. It has been demonstrated that a healthy man may consume drink, in twenty-four hours, which contains from two to two and a half ounces of alcohol without apparent injury, when all circumstances are as favorable as possible for the perfect action of all the bodily organs. But it by no means follows that it would be equally safe for a man in the varying and uncertain conditions of ordinary life to incur the risk of disturbing the nice balance of the physical adjustment upon which vigorous health depends by introducing into his organism an element which *may*, and more likely than not *will*, disorder the action of some one or more of the

delicate organs. Let him take just a little more than the exact amount which can be at once oxidized in the blood or other tissue, and it is carried on through the system as alcohol, to work its characteristic effects. In the stomach the alcohol may harden the albumin of the food, and so prevent its complete digestion. If strong enough, it may attack the albumin in the cells of the lining of the stomach itself. This is the reason for the well-known fact that alcoholic drinks do less harm if taken after a meal than if taken on an empty stomach. A large quantity of strong drink taken at once seems to paralyze the nerves controlling the absorbents in the stomach, and often results in sudden death. Passing into the circulation, alcohol, as we have already seen in respect to yeast, acts directly upon the vitality of the living cells, hindering their growth and, when strong enough, wholly destroying their vital power. Any excess beyond the amount which can be oxidized at once interferes with normal cell activity, and works various physiological evils, as pointed out in different chapters of this book. All these are the actions of a *poison*.

359. In the *stomach* alcoholic fluids of all sorts increase very greatly the flow of gastric juice, and it would appear that this stimulation might assist digestion. But since the alcohol is found to disappear wholly from the alimentary tract within half an hour, this direct influence upon the secretion of gastric and other digestive juices can be but slight. Moreover, excessive or abnormal stimulation of any organ results ultimately in the weakening of its functional power. In the healthy animal wholesome food supplies all the stimulus needed by the various digestive organs.

In the *intestines* alcohol is rapidly absorbed into the blood. By dilution with the juices of the mouth and the

stomach its power for direct injury has already been reduced; but if the work of the stomach has been imperfectly done because of its presence, more labor remains to the intestines, and that may disorder the whole system.

360. The portal vein carries the alcohol absorbed from the stomach and the intestine directly to the *liver*. Here its evil effects in developing disease are earliest and oftenest apparent. Alcohol in the liver, as in other places, greedily uses up the oxygen needed for the necessary vital operations. In that way it prevents the normal action of the hepatic cells, for not enough oxygen remains for them to do their work perfectly. Now the liver, as the largest organ in the body, has a correspondingly important part to play in the vital processes, and any interference with its functions is extremely serious. It is well known to physicians that a drunkard's liver presents a greatly modified appearance, which is seen to a less degree in the liver of a moderate drinker. Alcohol does not build useful tissue, but instead it promotes the abnormal deposit of fat cells, causing what is called "fatty degeneration." This is often seen in the liver of alcohol users and causes enlargement of the organ; the connective tissue, also, is sometimes inflamed and hardened. Because of the imperfect action of the liver, poisons which should have been neutralized are allowed to circulate through the system and undermine its health.

So it appears that throughout the digestive tract alcohol is liable to work harm to the organs more or less serious in proportion to the frequency of its use and its amount.

361. Other Sources of Danger from Alcoholic Drinks. — Many of the drinks containing alcohol contain also a mixture of nutritious substances, such as unfermented sugar and

other foods found in the vegetables used in the manufacture; though no one drinks those beverages for the sake of the trace of nourishing matter in them. But there are formed along with the alcohol in fermentation other products, some of which are known to be directly poisonous, while others are at least probably injurious. Fusel oil and various ethers are among these substances. Another source of danger is found in the frequent adulteration of alcoholic beverages. The great expense attending their manufacture leads to the use of inferior materials, impure sugars, defective fruits, etc., and to the addition of poisonous coloring and flavoring matters. In some cases even so virulent a poison as strychnine has been found. These adulterations still further menace the health of the users of such drinks.

362. The Most Dangerous Quality of Alcohol. — Bad as it is to suffer from enfeebled physical conditions, it is yet worse to become weak in mind and unstable in moral character. No one will deny that such weakness and instability are results of the excessive use of alcoholic liquors. But no man ever lived who deliberately determined to make himself a *drunkard*, when first beginning to taste the exhilaration of the moderate use of such beverages. Every one thinks he will confine himself to the small quantity which he believes will do him no harm. How is it, then, that in all the great cities of the world certain streets are by night full of the sounds of crazy drunken revelry; that prisons are crowded with criminals made such by involuntary acts when "in liquor"; that myriads of human beings tumble every year into drunkards' graves, dying as the beast dieth, all the beauty and dignity of life wrecked long before, all hope, all possibility of rescue long since abandoned?

We class alcohol among the foods because it comes within our definition of food, but in a higher degree than any other substance used for food, it possesses a peculiar power which is not characteristic of food. It is the power of developing a progressive craving, an uncontrollable appetite for itself, which is never satisfied, and which leads the wine bibber to long ever for more and stronger wine, or whisky, or gin, or brandy. It is easy to say, "I will never drink any more alcohol in a day than the two ounces and a half which science has proved can be wholly oxidized in the body, yielding force and conserving to the extent of its own service the physical powers." The man who speaks thus *may* indeed be able so to regulate his actions, but millions of his fellow-men have not been able to do so. Men do not rightly estimate the full force of the insidious power of alcohol to create an ever-growing appetite which demands ever more alcohol for its satisfaction. Bread and meat and milk and fruit, which build the tissues and supply the forces for vigorous and worthy life, do not create an abnormal appetite for themselves. Sometimes a man or a woman indulges in the excessive use of tea or coffee, and may possibly experience something of the unhealthy craving for those beverages which the drunkard has for his liquor. But harmful as the effect of such indulgence is upon the physical system, it does not so undermine the mental and moral health as does the alcoholic habit.

363. It is at least *perfectly safe* to avoid wholly the use of alcoholic beverages. One who does so is certain to escape the frightful danger of acquiring that overmastering appetite for alcohol, to satisfy which he *might* become willing to commit murder or arson, or any other crime, and for whose indulgence he *may* be led to ruin all his hopes of happi-

ness for this world and for the world to come, and crush out all joy from the lives of those dear to him. What is the wise course for a being endowed with reason?

Demonstrations and Experiments

111. *A General Dissection of the Digestive Organs* can be performed on the body of a rat, cat, dog, or rabbit. In this dissection other viscera besides the digestive organs should be examined. Just how much of the dissection is to be done by pupils, if any at all, must be left to the judgment of the teacher. Whether the actual class work takes on the nature of a dissection or merely of a demonstration, the attempt should be made to examine, as far as possible, every organ described in the text. To show the villi, cut out a piece of the wall of the small intestine, and after gently washing it examine the inner surface with a hand lens. Teeth of various animals can be obtained to show the arrangement in the jaws and the general structure and materials of a tooth.

112. *Minute Structure of Digestive Organs.* — Some prepared microscopical sections of various parts of the digestive tract will aid the pupil greatly in understanding the structure and properties of the alimentary organs. Very instructive are sections of the wall of the esophagus; of the stomach, showing the three muscular coats; of the small intestine; and sections of a salivary gland and of the liver. Tissues of any of the domestic animals can be used.

Experiments in Digestion. — It should be borne in mind that digestion carried on in test tubes is not normal, and that these experiments in digestion are merely illustrative.

113. *Salivary Digestion.* — To a test tube about half full of starch solution [1] add a little saliva and place the tube where the temperature can be kept at about 37° C. (98° F.). In a few minutes the starch solution becomes clear, and while at first it gave the characteristic reaction with iodine it now no longer turns blue, but if Trommer's test (Ex. 96) be applied, turns yellow, showing presence of sugar. To

[1] Rub a gram of laundry starch into a paste with a little cold water. Then add a hundred cubic centimeters of boiling water, and boil for a few minutes. Cool before using.

be sure that the sugar is a product of digestion, Trommer's test should be applied to the solution before saliva is added, and also to dilute saliva.

Prepare two other test tubes in a similar way, but boil the contents of one, and place the other on ice, or in a very cool place. From this conclusions may be drawn regarding the relation of temperature to the activity of the ferment of saliva.

The saliva of some persons has little or no digestive effect, hence this experiment will occasionally fail.

114. *Gastric Digestion.* — Fill three test tubes about half full of artificial gastric juice,[1] and three other test tubes with (1) water, (2) water containing a little powdered pepsin, and (3) a $\frac{2}{10}$ per cent muriatic acid solution, respectively. Place in each test tube a few shreds of fibrin. Fibrin is used because it is a solid proteid, and the progress of its digestion can be followed with the eye, without making special tests. Boiled white of egg may be used, but it digests more slowly. Boil one test tube containing artificial gastric juice, place a second on ice, and set away the other test tubes in a warm (37° C.) place.

In a short time the fibrin in the tube of gastric juice kept in the warm place is seen to be much swollen, and gradually it disappears in solution. Compare the test tube with the others. What effect has temperature on gastric digestion? Is the presence of pepsin necessary? Does pepsin alone (in water) digest the fibrin?

115. *Action of Gastric Juice on Milk.* — To a test tube about half full of fresh milk, add a little artificial gastric juice that has been neutralized by the addition of dilute carbonate of soda. Keep at a temperature of about 37° C. (98° F.). In a short time the milk curdles. In previous experiments on milk, curdling was produced by acids; here, since the gastric juice was neutralized, it is due to some other cause. To the test tube add a little dilute muriatic acid to acidulate the contents, and keep it in the warm place for several hours. The casein is finally digested in the presence of acid, forming a straw-colored fluid.

116. *Action of Rennet on Milk.* — To some fresh milk in a test tube add a little commercial extract of rennet, and keep at a tempera-

[1] Add a little powdered pepsin (to be obtained at a druggist's) to a $\frac{2}{10}$ per cent solution of muriatic (hydrochloric) acid.

ture of about 37° C. The milk curdles in a few minutes. In the previous experiment the milk was curdled by the rennin ferment in the artificial gastric juice.

117. *Action of Pancreatic Juice on Starch.* — Repeat Ex. 113, using, instead of saliva, artificial pancreatic juice.[1]

118. *Action of Pancreatic Juice on Proteids.* — Repeat Ex. 114, using artificial pancreatic juice instead of gastric juice, and carbonate of soda solution instead of muriatic acid.

119. *The Emulsifying Effect of Pancreatic Juice.* — Rub together, in a mortar, some olive oil, or cod-liver oil, with pieces of fresh pancreas. An emulsion results. Shake together in a test tube some olive oil and a little artificial pancreatic juice, as used in preceding experiments. An emulsion occurs as before. Boil some artificial pancreatic juice to destroy the ferment. It still forms an emulsion with oil. In the experiments on fats (Exs. 97–100) it was seen that an alkali, or a soluble proteid, forms an emulsion with fats. Natural pancreatic juice contains both alkali and proteids. Hence, even when boiled, pancreatic juice emulsifies fats.

120. *Bile.* — Obtain bile at a slaughterhouse. Observe its color. Test with litmus paper. It is neutral or alkaline if fresh.

121. *Action of Bile in Fats.* — Shake some olive oil in a test tube, with five times its bulk of bile. Make a similar mixture of olive oil and water, and observe in which case the emulsion lasts longer. Shake up bile with olive oil, to which a little oleic acid is added. The emulsion lasts longer than before.

122. *Action of Bile in Filtration and Absorption.* — Into each of two small funnels of exactly the same size, put a filter paper. Moisten one with water and the other with bile. Pour into both equal amounts of almond oil, and after covering to prevent evaporation, set aside twelve to fourteen hours. The oil passes through the filter moistened with bile, but scarcely at all through the other.

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[1] Add a little powdered pancreatine to a 1 per cent solution of carbonate of soda. Commercial pancreatine commonly contains both the starch-digesting ferment, *amylopsin*, and the proteid-digesting ferment, *trypsin*.

CHAPTER XVIII

THE DUCTLESS GLANDS

364. The ductless glands are organs whose functions are not yet well understood. Unlike other glands, they do not form a definite secretion poured forth by means of ducts. Some of what we call "true glands" have been shown to send into the lymph and blood, in addition to the secretion passing through their ducts, material of great importance to the healthy working of the body. This is true of the liver and of the pancreas, though these additional functions are only partly understood. It is probable that the ductless glands have similar offices in the economy of the system.

365. **The Spleen** (Figs. 94 and 95, pp. 163 and 165). — The largest of these peculiar glands is the *spleen*, a dark purplish body of variable size and spongy texture, lying on the left side of the abdominal cavity, just below the stomach. In the meshes of the tissue of the spleen is a soft substance called *spleen pulp*. This consists largely of red blood corpuscles and colorless cells, some of which are like the white blood corpuscles.

366. **The Blood Supply of the Spleen.** — The *splenic artery*, a branch from the aorta, carries an abundant supply of blood to the gland (Fig. 94), and the smallest branches of the artery open directly into the spleen pulp. This is the only place in the body where the blood comes

into actual contact with the cells and fibers of a tissue. The veins of the spleen unite to form the *splenic vein*, which carries the blood into the portal vein and so to the liver.

367. Functions of the Spleen. — Little is yet positively known as to the functions of the spleen. That the organ has some connection with digestion is shown by its enlargement as soon as gastric digestion is completed. It has also some close relation to the liver, and it is understood to be engaged, like the lymphatic glands, in the manufacture of *white corpuscles*. In some animals it forms the colored corpuscles likewise, but we do not know whether that is true of the human spleen. It is thought by some that the spleen is the organ where the red corpuscles which are worn out undergo disintegration, their coloring matter being carried to the liver and there used to form the coloring matter of the bile.

368. The Thyroid Gland is a body whose two lobes lie on the sides of the trachea (Fig. 117). The disease called *goiter* is an enlargement and alteration of structure of the thyroid, and the effects sometimes extend to the impairment of muscular and nervous activity and to a semi-idiotic condition of mind, resulting in death if the whole gland is affected. The diseased condition may be relieved or cured by grafting a portion of the thyroid gland from an animal under the skin of the afflicted one, or by adding

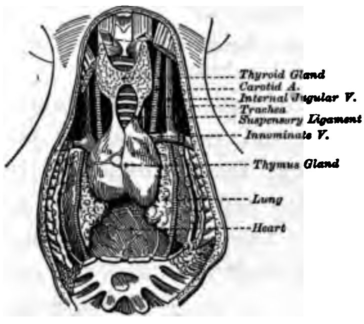

Fig. 117. — Thyroid and thymus glands of an infant.

new thyroid tissue to the food, or even by subcutaneous injection of the juice of a healthy gland. It is concluded that the gland either forms, or helps to form, some substance needful to health, or has some place in the destruction of deleterious substances in the system, but positive knowledge in respect to it is lacking.

369. The Thymus Gland lies in the thorax beneath the sternum (Fig. 117). It is a small organ, weighing only about half an ounce at birth. After growing with the body until the second year it gradually shrinks away, and before the age of sixteen usually disappears. Its use is quite unknown. The thymus of calves and lambs forms an article of food called sweetbread.

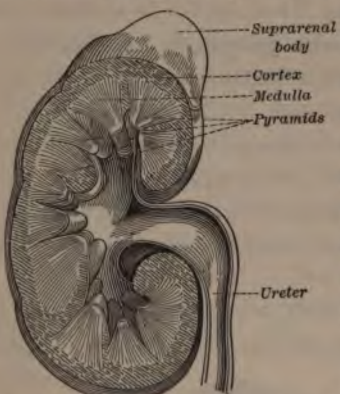

Fig. 118. — Longitudinal section of kidney.

370. The Suprarenal Capsules (Fig. 118) are small organs resting on the upper portion of the kidneys. They are supplied with an abundance of blood vessels and nerve fibers and nerve cells. It has been found that their removal from animals is invariably and quickly fatal. All that can yet be said as to the function of these bodies is that they appear to form something which is essential to the healthy tone of the muscles.

CHAPTER XIX

THE ORGANS OF EXCRETION

371. We have already learned that a double vital process is continually carried on by the living cells in the tissues of the body. One side of this vital activity is the taking up, from the blood, of oxygen and the nutrient material which the blood receives from the food in the alimentary canal, and it results in growth and repair. The other side of cell activity is the oxidation, or decomposition by burning in the tissues, of worn-out matter, and its return to the blood to be expelled from the body. This removal of waste matter from the blood is called *excretion*. The waste material from the tissues leaves the body under three principal forms,—as *carbon dioxide*, *water*, and *urea*. The *lungs*, as we have seen, not only supply oxygen to the blood, but also give off daily a large amount of water and carbon dioxide. Two other organs also have the function of excretion. They are the ***skin*** and the ***kidneys***. The skin gives off water and certain salts; the kidneys remove urea and other nitrogenous waste, along with a large amount of water.

372. The Skin as an Excretory Organ. — We have studied the skin as an organ of sensation, and have learned something of its structure and its use as a sense organ and as a protector of the more delicate parts. Now we are to study it as a remover of waste.

373. Structure of the Skin. — It will be remembered that the skin is composed of two layers: the *epidermis*, composed of many layers of cells; and the *dermis*, or *true skin*, in which are found the papillæ, blood vessels, and nerves, with the end organs for touch and glands of different sorts (Fig. 49, p. 83).

374. Perspiration. — The excretion of the skin is called *perspiration*, or *sweat*, and consists of water, a little dissolved salt, and some fat. When the perspiration is evaporated from the skin as fast as it is secreted, it is called *insensible perspiration;* but if the quantity is larger, so that it collects upon the surface, we call it *sensible perspiration*.

When the amount of sweat produced is scanty, it is acid in chemical composition; but when the discharge is profuse, it is alkaline. This difference is understood to be due to the mixture of the products of the *sebaceous glands* with those of the *sweat glands*. The former are extremely minute glands pouring their secretions into the *hair follicles*. Their product is acid and fatty, and is constant, or nearly so, in quantity, while that of the sweat glands is alkaline and variable in amount.

375. The Sweat Glands are very abundant over the whole skin. They consist of coiled tubes lying deep in the dermis, and the duct of each reaches the surface by a corkscrewlike channel.

376. The Nerves controlling the Sweat Glands are of two or three different sets. Those affecting the blood circulation, vasomotor, diminish the secretion of sweat by narrowing the size of the blood vessels, and increase it by dilating them. The special secretory fibers, when stimulated, cause production of perspiration. Still other nerve fibers supply the plain muscle fibers of the glands and regulate the expulsion of the fluid. All these nerve fibers are

found in the same nerve trunks. There are subsidiary nervous centers for this secretion in different parts of the spinal cord; but the chief center controlling the others is the medulla oblongata, and the nerve fibers for the sweat glands run in the nerve trunks supplying the different parts of the body. For example, the sciatic nerve, supplying the muscles of the leg, carries secretory fibers to the sweat glands of the leg.

377. **Functions of Perspiration.** — By means of the sweat glands waste water taken from the blood continually passes into the air. The amount varies greatly, but may be said to average about one and a half pints daily. A very little carbonic acid and solid matter are found in the sweat, along with the fat from the sebaceous glands, and a mere trace of urea.

Besides the removal of waste matter, another important function belongs to the skin in connection with perspiration. It is well known that as water passes from the liquid to the gaseous state a large amount of heat becomes latent, and this heat is supplied by adjacent bodies. Hence it is clear that by the evaporation of the perspiration the surface of the body is cooled, and the sweat thus becomes a regulator of the temperature of the body, the amount of evaporation depending upon the state of the body and of the surrounding air.

The amount of sweat secreted is also affected by nervous impulses from the emotional centers in the brain. Fear, for example, sometimes causes profuse sweating. Strong muscular activity, developing heat and stimulating the circulation, increases perspiration. A low temperature in the surrounding air constricts the blood vessels of the skin, and so diminishes the production of sweat and prevents loss of heat from the surface.

378. The Kidneys (Fig. 118) are bean-shaped organs, lying on each side of the lumbar portion of the backbone. They are dark red in color, about four inches long, two and a half broad, and about one inch in thickness. At the center of the concave, or inner edge, of each kidney the arteries enter and the veins leave the organ. The arteries are branches of the aorta; the veins empty into the inferior vena cava. From the same portion of each kidney passes another tube, the *ureter*, which conveys the *urine* secreted by the kidneys to the sac called the *bladder*, in the lower part of the abdomen, for storage. The ureters pass obliquely through the wall of the bladder, so that return of the contents of the latter is prevented.

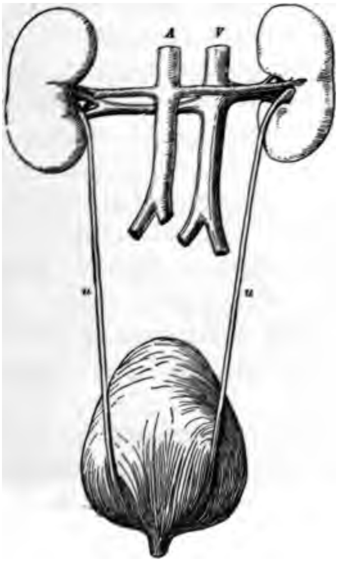

Fig 119.—The kidneys and bladder viewed from behind.

A aorta, from which the renal arteries extend to the kidneys.
V inferior vena cava, from which the renal veins extend to the kidneys.
u ureters.

379. Structure of the Kidneys.—By dividing a kidney lengthwise through the middle, two distinct parts may be seen: an outer, granular portion, called the *cortex*, lying next to the inclosing capsule, and an inner *medullary portion* (Figs. 118 and 120). The latter consists of a number of conical parts, called *pyramids*, with their bases toward the cortex. In the cortical portion the tiny *uriniferous tubules* commence around tufts of blood capillaries (*glo-*

meruli) and are gathered by a complicated arrangement into larger divisions, and finally empty into the enlarged upper portion of the ureter. From the little bunches of capillaries spreads throughout the cortex a fine network of capillary tubes, which gather into veins and pour the blood into the *renal vein*.

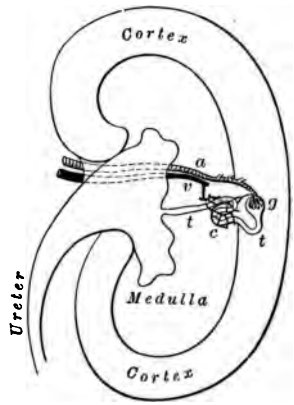

Fig. 120. — Diagram of a longitudinal section of a kidney.
a renal artery.
c capillaries.
g glomerulus.
t uriniferous tubule.
v renal vein.

380. Nervous Supply of the Kidneys. — The kidneys receive nerves from the *renal plexus* upon each side. This is composed of both white and gray nerve fibers and of nerve cells. They come from many sources, but mainly from the sympathetic system by way of the solar plexus. The renal plexus has thus indirect connection with the vagus and with other nerves distributed to the internal organs. These nerves seem to have only vasomotor functions. As yet, we are unable to trace the special secretory nerves of the kidneys.

381. Functions of the Kidneys. — The food which we eat, after rendering to the tissues of the body its proper service, is converted into the waste products *water*, *carbon dioxide*, small quantities of *salts*, and *urea* (or some substance closely allied). The first two excretions result from decomposition of the carbohydrates and fats, while from the proteids come certain salts and nitrogen. These last are excreted almost wholly by the kidneys, along with a large quantity of water and a very little carbon

dioxide. To the kidneys, then, belongs the important function of removing from the body the waste product of nitrogenous food in all the living tissues.

382. Urea. — The final result of the changes which nitrogenous foods undergo is *urea*, and its chief ultimate source is the most abundant tissue — muscular tissue. There is, however, no urea in the muscles. Other steps in its production lie between the muscles and the kidneys. The spleen, lymphatic glands, and other glands have to do with its formation, but the final and most distinctive changes appear to occur in the liver. If the urea is not removed from the system, it destroys life. The quantity daily secreted by the human organism is about five hundred grains, which is normally 2 per cent of the total excretion from the kidneys.

383. Relation between the Kidneys and the Skin. — The relation between the skin and the kidneys is such that if one channel of excretion becomes clogged, extra labor appears to be thrown upon the other. If perspiration is checked, there is, along with diminished activity of the sweat glands, constriction of the blood vessels of the surface, followed by dilation of those of the viscera, which permits an increased flow of blood in the internal organs, including the kidneys. The secretion of the kidneys, therefore, becomes more abundant. When by warmth or exercise the sweat glands are stimulated, the reverse is the case: the vessels of the skin are dilated, while those of the abdomen are constricted, and the renal secretion becomes scanty.

384. The Kidneys and the Alimentary Canal. — Still more important seems to be the connection between the amount of the kidney secretion and the water absorbed by the walls of the alimentary canal. When a large quantity of water is drunk, it passes directly into the circulation, and,

though the general blood pressure is not raised, it does appear to affect directly the action of the kidneys and to increase the excretion.

385. The Kidneys and the Nervous System. — The state of the central nervous system greatly affects the activity of the kidneys. This may be by the passage of emotional impulses, originating in the brain, along *vasodilator* fibers to the kidneys. The blood vessels being thus dilated, the activity of the glands would be stimulated. Very large quantities of almost pure water are sometimes thus eliminated under emotional excitement.

386. Excretion by the Alimentary Canal. — Portions of the food taken into the stomach are unfit to enter into the structure of the tissues, and are expelled unchanged through the intestines. A small amount of true excretion also takes place there, by which used-up matter is removed.

387. Autointoxication, or Self-poisoning. — Even under normal conditions man's organism is "a receptacle and a laboratory of poisons." They are taken in with the food in the form of those minute bodies which cause putrefaction. The process of katabolism (§ 283) is a manufacture of poisons, and many of the secretions, such as the saliva and the bile, are poisonous. A large number of poisonous substances are formed in the intestines, and several forms of deadly poison have been discovered in the urine. All of the poisons made by the tissues, and some of those manufactured in the digestive tube, are poured into the blood, so that even normal blood contains poisons, though an excessive amount of the same poisons threatens health and life. Many diseases are now understood to result from the *self-poisoning* due to disordered nutrition, along with the opportunities for infection from specific germs which are always present; and reabsorption of excrementitious

matter once separated from the blood for rejection is a danger to be guarded against.

388. Attention has already been called to some of the ways by which man is protected from the injurious products of his own organism (§§ 335, 336, 338). The gastric juice contains more than enough hydrochloric acid to prevent all fermentation in the stomach; but in the intestines its action is neutralized by the alkalis of the intestinal juices. In the intestines a variety of poisons are found, and when digestion is disordered the number and quantity may be dangerously increased. Some of these are excreted, while others are absorbed into the blood. The liver is the great defense against the poisons in the blood, many of which are caught by that gland, and either transformed or passed on to be removed from the body by means of the kidneys. By the lungs enough carbon dioxide is removed from the body every day to poison a man to death many times over; but other injurious matters are found in expired air, especially in the case of persons suffering from defective nutrition. The skin also plays its part in the elimination of poisons, and the peculiar odor of the perspiration in certain abnormal conditions is a guide to the physician as to the internal state of the system.

All these facts show the immense importance of keeping constantly open and in healthy condition the various channels of excretion.

389. Influence of Alcohol upon Excretion. — If the waste substances constantly formed in the body are not promptly removed, they tend to poison the system. When the organism is at a high level of health, the breaking down of tissue by oxidation, which produces waste, goes on rapidly and vigorously. When this is retarded, as we have seen

it to be when alcohol is introduced into the circulation and uses up the oxygen which should be applied to the oxidation of food, then the weight may increase, but it is by the retention of poisonous matter which ought to be removed. No other one cause creates so much disease of the kidneys as does the use of alcohol. Imperfect oxidation of food develops poisons which the kidneys are overtaxed to remove. This may be caused by eating too much, or by eating unwholesome food, or too much of certain kinds of food, as sugar especially; or it may be caused by alcohol. "Fatty degeneration of the kidneys" is a frequent result of the use of alcoholic drinks. The cells of the tissues become so altered, also, that they fail to act normally by removing only the poisonous substances, and they allow the valuable elements in the blood to be drained off with the waste. This is seen in the serious disease called "Bright's disease" in which the albumin which is necessary to health is excreted by the kidneys.

DEMONSTRATIONS

123. *Dissection of the Kidney.* — Procure a kidney of a sheep or of a pig. As much as possible of the ureter should remain attached. The kidney is seen to be inclosed in a *capsule*. Remove the latter, and notice the shape of the kidney and the enlarged attachment of the ureter. Split the kidney lengthwise parallel to the broad surface, and observe on the outside of the section a layer, the *cortical* layer, differing in color from the more internal, *medullary*, portions. Notice the projections, *pyramids*, of the medullary portion into the *sinus*. The latter is a cavity in the concave side of the organ, continuous with the cavity of the ureter.

124. *Minute Structure of the Kidney.*— For this some prepared sections will be needed: (1) section showing general structure of cortex and medulla, with uriniferous tubules plainly demonstrated; (2) section showing blood vessels injected; (3) a cross section of the ureter.

CHAPTER XX

THE HEAT OF THE BODY

390. Inanimate bodies tend constantly to assume the temperature of the air, water, or other objects near them. An object which has been heated gives out heat to surrounding objects until all are of the same temperature. There is, as we say, a tendency to equilibrium in respect to temperature.

391. Animal Heat. — Warm-blooded animals (birds and mammals) maintain within their bodies, summer and winter and indoors and out, with slight variations, the same degree of heat, and are independent of their surroundings in that respect.

392. Temperature of the Body. — In order that the vital processes necessary to human health and comfort may go on under the most favorable circumstances, it is necessary that the body should maintain a temperature of from 98° to 99° F. (from 36.6° to 37.2° C.). If it rises much above or sinks much below this, it is an important indication of abnormal condition in some part of the system. We may be exposed to extreme heat and to severe cold without any marked change in the bodily heat. The skin, it is true, being in contact with external objects, is usually cooler than other parts. Some of the internal organs have in health a temperature several degrees higher than the general average, and any special activity of an organ develops

a local excess of heat. A group of muscles, for instance, by their contraction, produce heat. A gland, by the act of secretion, does the same. But the tide of blood, flowing swiftly through the system and bathing every part, tends to equalize the heat throughout.

393. **The Sources of Animal Heat** are of two sorts,—direct and indirect. The great source of heat is the combustion of food, that is, the oxidation which takes place in the living cells in all parts of the body. This is equal to the amount of heat which would be given off by the burning in the open air of the same quantity of food which is consumed in the body. The muscles and the glands are the parts in which the greatest amount of oxidation takes place. Some little heat is also received by the body in hot foods and drinks.

Heat is produced indirectly by the transformation of other forms of energy. Friction of one part upon another—as of the blood along the walls of the blood vessels—becomes heat. All mechanical work, all nervous activity, and the slight manifestations of electricity within the body liberate heat.

394. **Regulation of Temperature** is accomplished in two ways; viz. by variation in the loss of heat and by variation in its production.

Variation in loss of heat. Everything which leaves the body carries away a portion of its heat. The expired air, the perspiration, the excretions, are sources of loss; and radiation and conduction of heat from the surface are continually going on, as well as evaporation from the skin and the lungs. The skin is the chief regulator of loss. By clothing the body a portion of the loss by radiation is prevented, and we have already seen (§ 376) how the secretion of sweat, and hence the cooling of the surface by

evaporation, is affected by the vasomotor and nervous mechanisms of the skin.

Variation in production of heat. The processes of digestion are attended by the setting free of heat. The temperature rises after a meal, while a marked condition in starvation is the fall of the bodily temperature. Muscular contraction always going on develops heat, and the more active the muscles are, the greater is the amount of heat produced.

There is also evidence, from numerous experiments, of direct nervous control over the production of heat. Afferent impulses from the skin or other organs reach the central nervous system and some restricted "heat center" not yet anatomically made out in the central part of the brain. The exact path of these impulses is not yet ascertained. The stimulation of the heat center, wherever it may be placed, gives rise to efferent impulses by which activity in the tissues is increased and heat is produced.

395. Clothing. — Though the body is able to endure a large amount of exposure to heat and cold without injury, yet the mechanism for heat production may be overtaxed, as well as the digestive, the muscular, or the nervous system. Any such overtaxing interferes with the other functions of the body. Excessive exposure to cold, or insufficient clothing, forces the body to use an undue amount of energy in manufacturing heat, and other parts of the vital economy suffer; growth in the young is interfered with, and mental and muscular effort become difficult. The clothing worn should therefore be such as will assist in preserving the natural temperature of the body, and the amount and the material will vary with climate and season, as well as with the age, habits, and health of the wearer.

While clothing is designed to prevent too rapid radiation of heat from the surface, it should still permit the evaporation of perspiration, for an accumulation of moisture upon the skin may expose one to dangerous chills.

396. Fabrics of *wool* have been found to possess more fully than any other materials the qualities desired for clothing. They are so light and porous as to admit of sufficiently free evaporation and the circulation of air; and as wool is a bad conductor of heat, it retains the heat of the body, while it holds in its meshes a considerable quantity of air, which is also a nonconductor of heat. In variable climates, such as that of our Northern states, it is wise, at least for those in delicate health or especially sensitive to changes of temperature, to wear wool next the skin at all seasons. The gentle friction of woolen garments against the skin tends to prevent clogging of the pores, to promote even circulation, and in general to keep the surface in a healthy condition.

397. *Silk* is less valuable than wool in preserving heat and permitting evaporation, though better than cotton or linen. It may be worn next the body when wool causes irritation of the skin.

398. *Linen* is less useful than other materials for the innermost garments, as it quickly becomes saturated with moisture. *Cotton*, being more porous, answers the purpose better. In respect to all these materials the weaving of the fabric has much to do with its value for clothing. Closely woven cloth of hard-twisted threads should not be chosen for underwear, but rather that of soft, loosely twisted fibers, loosely woven.

399. *Fur* is indispensable in the coldest climates, as it retains better than anything else the bodily heat. But it prevents the evaporation of perspiration, and should not

be worn in moderate weather ; nor should fur garments be retained indoors — as when sitting in an assembly room. The practice of muffling the throat in wraps of fur should be avoided, as liable to render the larynx unnecessarily sensitive to cold, and to cause the evil it is intended to prevent.

400. *Waterproof* wraps, which prevent the escape of perspiration, should be worn only as a protection from rain or snow.

401. Light-colored clothing reflects the rays of heat and absorbs but little warmth, while dark colors absorb heat and reflect little. Hence the common custom of wearing light-colored garments in summer and dark ones in winter is founded in reason.

402. Frequent changes of clothing, especially of that which touches the skin, are needful. The pores of a fabric soon become filled with the poisonous waste matters secreted by the skin. The clothing worn by day should never be worn during the night also. If it is to be resumed in the morning, it should be exposed to free circulation of air during the night. Night clothes and all bedding should be carefully sunned and aired each day.

403. It is important that all clothing and bedding should be thoroughly dry. Damp clothes do not retain the natural heat of the body, but rapidly conduct it away, leaving the surface chilled and the system exposed to attacks of disease. Especially should shoes and stockings which have become wet be removed as soon as possible. Many a serious or fatal illness has resulted from neglect of this precaution. Damp bedding is especially dangerous to health, as the relaxed condition of the body during sleep renders it an easy prey to every cause of disease.

404. Care should be exercised in changing from the warm clothing of winter to the thinner garments needed in the spring. It is most prudent to make changes first in the outer clothing, retaining the warm inner garments until the mild weather is well established. Often in the Northern states it is necessary to return to heavy winter wraps after a season of high temperature.

In the early autumn, too, when cold, damp evenings and nights follow hot, sunny days, judicious attention to clothing will often ward off the intestinal and febrile diseases prevalent in that season. It is frequently wise to change the underclothing with the approach of night, putting on the warm wool which was perhaps intolerable at midday. Many physicians advise as a safeguard the wearing of a broad woolen bandage over the abdomen both by day and by night.

405. The Bodily Heat as affected by Alcohol. — The paralyzing effect of the use of alcoholic drinks, upon the muscles in the walls of the minute blood vessels, has been mentioned in connection with the muscles, the circulation, and respiration. It should be referred to also in connection with the subject of this chapter.

Because alcohol is quickly oxidized, and because heat is produced in the process, it was long believed to be of value in maintaining the heat of the body. A different view now prevails as the result of much observation and experiment. Travelers in Arctic regions and others exposed to intense cold agree that those who use no alcohol whatever are far better able to resist the cold than are those who indulge in it. Physiologists show by careful experiments that though the temperature of the body rises during digestion of food, it is lowered for some hours when alcohol is taken. The flush which is felt

upon the skin after a drink of wine or spirits is due in part to an increase of heat in the body, but also to the paralyzing effect of the alcohol upon the capillary walls, allowing them to dilate, and so permitting more of the warm blood of the interior of the body to reach the surface. There it is cooled by radiation, and the general temperature is lowered.

PART IV

THE NERVOUS SYSTEM

All our previous study has had to do, directly or indirectly, with the nervous system, with its methods of action, its instruments, its nutrition, its arrangement and functions. Now we are to examine its wonderful and delicate mechanism more in detail, to inquire further into the functions which the various parts fulfill, and into the manner of life which study and experience have shown to be most conducive to the preservation of the most important part of the human organism in health and efficiency.

Even the limited amount of knowledge upon this great subject which is within the reach of young students may be made valuable in enforcing the necessity of hygienic living, and also as a basis for a ready appreciation of that larger revelation respecting the nervous system which science will from time to time unfold.

In presenting this fuller description of the nervous system some repetition of the statements given in Chapter III is found necessary.

Fig. 121. — The nervous system.

CHAPTER XXI

ANATOMICAL DESCRIPTION

406. Composition of the Nervous System. — The nervous system is made up of *nerve centers*, *nerves*, and *peripheral end organs*. These, though really constituting a single system for the whole of man's organism, are commonly described in two separate groups, or systems: the *cerebro-spinal* or *central* and the *sympathetic* or *ganglionic*.

The *nerve centers* are the brain and spinal cord (often called the cerebro-spinal axis), and little knots of nervous matter found in different parts of the body, along the course of the nerves, called *ganglia*. All nerve fibers arise in the nerve centers.

407. Nervous Elements. — We have learned that nervous tissue exists in two forms: *gray matter*, which is almost wholly composed of nerve cells, and *white matter*, which is almost wholly composed of nerve fibers. Nerve fibers and nerve cells constitute the *nervous elements*.

408. The Nerve Cell. — Nerve cells are microscopic, irregular bits of protoplasm like other cells. Each contains a large *nucleus*, within which is a *nucleolus*, and usually each cell sends off one or more fine branches, or processes (Fig. 122). Sometimes these are so numerous as to give the cell a stellate appearance. Nerve cells are found only in the central nervous system, in the

ganglia, and in the peripheral terminations of certain nerve fibers.

Fig. 122. — Nerve cells from the spinal cord.

A nerve cell with all its processes. *B* body of cell, showing nucleus (*N*).

409. The Axis Cylinder, or Neuraxon. — One of the processes of the nerve cell — and as a rule only one — becomes what is called the *axis cylinder* of a *nerve fiber*. It is a protoplasmic thread continuous with the substance of the cell and usually inclosed within a sheath. Axis cylinder processes give off, usually at right angles, fine side branches which ramify in the adjacent nerve substance (Fig. 123), and the final ending of the axis cylinder itself is in many minute divisions. Many or most of the nerve cells have other processes which do not become axis cylinders, but end in fine twiglike divisions in the gray matter around them.

410. The Nerve Fiber (Fig. 124). — The essential part of every nerve fiber is the central protoplasmic core, which is always the axis cylinder process of a nerve cell. There is hence, after all, only one fundamental form of nervous matter, viz. the protoplasm of the nerve cell.

The central thread of a nerve fiber may have two inclosing sheaths. A layer of white, oily matter immediately surrounding the axis cylinder is called the *medullary sheath*, or sometimes the *white substance of Schwann*. Outside of this is a coat of thin, elastic membrane called the *primitive sheath*, or *neurilemma*. The latter covers its fiber from end to end, but the medullary sheath is broken at frequent intervals, and between the breaks the microscope shows along the course of the axis little nuclei buried in minute masses of protoplasm.

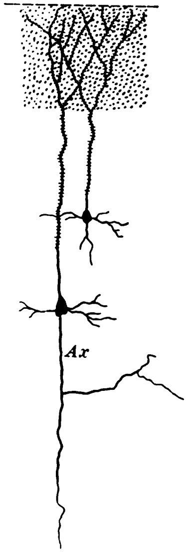

Fig. 123.—Nerve cells (pyramidal) of the cortex of the cerebrum.

Ax axis cylinder process.

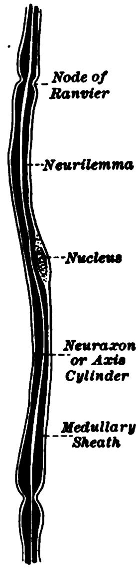

Fig. 124.—Portion of a medullated nerve fiber.

In some nerve fibers the medullary sheath is wanting, leaving only the neurilemma inclosing the axis cylinder. These are called *nonmedullated nerve fibers*. The medullary sheath is brilliant, shining white in color, and gives to the nerve its characteristic white appearance. The nonmedullated fibers, therefore, are gray.

Nerve fibers may be very short or they may be many feet in length. Every nerve fiber originates in a nerve cell, but there are several ways in which it may end, as has already been shown.

411. A Nerve is a bundle of nerve fibers bound together

by a little connective tissue in which run blood vessels and lymphatics, the whole inclosed in a sheath called the *perineurium*. The nerves from the central system are composed chiefly of medullated fibers, with which are bound up a few nonmedullated ones, while the nerves of the sympathetic system are made up almost wholly of the gray nonmedullated fibers.

412. A Ganglion is a little group of nerve cells forming a nervous center. As a rule (to which the spinal ganglia form an exception), the nerve fibers running from the central system to a ganglion are medullated, while those passing from the ganglion toward the periphery are nonmedullated and also more numerous.

413. Neuroglia. — The fibers and cells of both the gray and the white nervous matter are supported by a tissue called *neuroglia* (Fig. 125), which is composed of extremely fine fibers and cells. It differs chemically and in origin from the connective tissues, though like them in function.

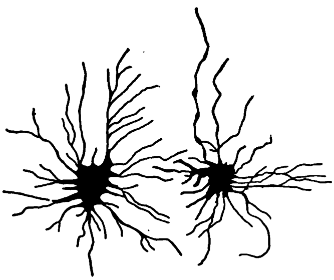

Fig. 125. — Neuroglia cells.

414. The Nerve Unit or Neuron. — A nerve cell, with its two sorts of processes, constitutes a *nerve unit*, or *neuron* (Fig. 126). That is, the whole nervous system is built up of an indefinite but enormous number of these units, supported by neuroglia and connective tissue. A nerve cell sends off one process (rarely more), which is prolonged into the axis cylinder, or *neuraxon*, while the numerous other branches, called *dendrons* or *dendrites*, almost immediately break up into fine twigs or brushlike

divisions. The dendrons are thought by some to be concerned only in absorbing nutriment for the nerve cell, while other investigators believe them to have also some part to play in the conduction of nerve impulses. Each neuron is anatomically independent of every other. There is no continuous path from one nerve cell to another. The fine branches from one cell mingle and interlace with those of another cell, but do not become connected with them to form a continuous channel, any more than do the interlacing branches of two trees standing side by side form communicating channels for the passage of the sap of one to the other. Nervous influences do indeed pass from one nerve unit to another by some method not yet understood, perhaps by a process similar to that of *electrical induction;* but the old idea of an uninterrupted channel for the passage of a nervous impulse from center to periphery and from periphery to center is now abandoned. There may be several breaks in the course of transmission, as there often are in the sending of a telegraphic message. The two sorts of branches also preserve their identity from beginning to end of each minutest filament. There is no real network of nerve fibers in the nervous system.

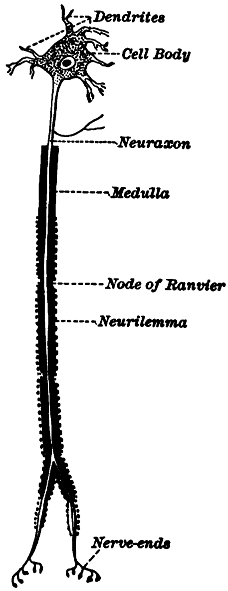

Fig. 126. — Diagram of a neuron or nerve unit.

415. The Spinal Cord (Fig. 18, p. 28) is a column of nervous matter from fifteen to eighteen inches in length in the adult, from the *foramen magnum*, through which

its fibers pass into the brain, to the fine gray filament which forms its termination in the lumbar vertebræ. A cross section shows it to be composed of white fibrous matter, surrounding a central core of gray cellular matter (Fig. 127). The gray matter presents in section a rough outline of the letter H. In the middle of the cross bar, or isthmus, connecting the two sides of the letter, is a minute channel which extends the whole length of the cord and on into the brain. The ends of the letter H which point forward are club-shaped and are known as the *anterior horns* of the gray matter of the cord, while those pointing backward are pointed and are called *posterior horns*. The last cut through the white matter nearly to the surface of the cord.

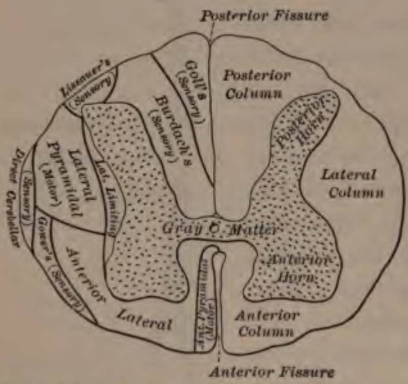

Fig. 127.—Diagram of a cross section of the spinal cord, showing the divisions of the white and gray matter.

The right half shows the threefold division of the white matter commonly described; the left half shows the physiological divisions as they are at present understood.

The white matter of the cord is composed of medullated fibers, running for the most part longitudinally, together with fibrous connective tissue and neuroglia. These fibers are arranged in several different strands, or bundles, and their areas have been carefully mapped out and named. In each half of the cord is an *anterior*, a *lateral*, and a *posterior* column, named from their positions and separated from one another by the shallow depressions seen in the

surface of the cord. The gray matter consists largely of nerve cells with many branching processes, but there are also many delicate nerve fibers, together with the supporting neuroglia. The cord is divided into symmetrical halves by fissures before and behind, the *posterior fissure* being the deeper, and the *anterior* wider and more distinct. Neither of the fissures cuts quite through the white matter to the gray in the center.

416. Spinal Nerves. — From the grooves nearest the anterior fissure spring, by many fine rootlets, the *anterior roots*

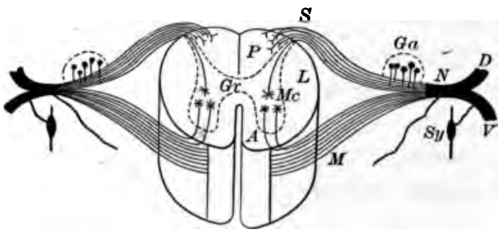

Fig. 128. — Diagrammatic cross section of the spinal cord, showing the origin and the chief divisions of a spinal nerve.

A anterior column of white matter.
D posterior branch of nerve trunk.
Ga ganglion on the posterior root of the nerve, containing the cells from which arise most of the fibers of the sensory root (*S*).
Gr gray matter of the cord.
L lateral column of white matter.
M anterior or motor root of the nerve.
Mc motor cells from which arise the motor nerve fibers.
N main trunk of the nerve.
P posterior column of white matter.
S posterior or sensory root of the nerve.
Sy ganglion of the sympathetic system which communicates with the spinal nerve.
V anterior branch of nerve trunk.

of the spinal nerves, while the *posterior roots* of the same nerves appear to rise near the other groove on the same side (Fig. 128). The two roots soon unite;—but before

their union the posterior root passes through a little knot of gray matter, called the *spinal ganglion.*

The cells of the anterior horn of the gray matter of the cord are large and branching, and each cell sends off an axis cylinder process which passes out in an anterior nerve root. Careful experiments have shown that the fibers in the posterior nerve roots of spinal nerves arise in the spinal ganglion. The nerve fibers which form this posterior root are axis cylinder processes from nerve cells in the spinal ganglion. As they pass out from the ganglion each divides into two branches, one of which goes to form a sensory nerve fiber in the spinal nerve. The other turns back and enters the spinal cord, where it again divides, its fibers ending variously. The main division of the branch from the ganglion passes up to the brain, giving off fine collaterals which end, by "arborizing" (as the brushlike ending is called), round nerve cells at different levels in the cord. In general, the posterior root fibers travel upward mainly in the white columns of the cord, while only a few fibers enter the gray matter of the cord.

417. Thirty-one pairs of spinal nerves issue from the spinal cord (Fig. 18, p. 28), each nerve containing both afferent, or sensory, nerve fibers from the posterior root, and efferent, or motor, fibers from the anterior root. These fibers remain distinct from each other for their whole length. The spinal nerves are distributed by many branches to the skin and skeletal muscles; they also form connection, by what are called communicating branches, with the ganglia of the sympathetic system (Figs. 128 and 136), and are afterward distributed to the viscera. The whole of the sympathetic system may be regarded as simply the development of these communicating branches from certain spinal nerves.

418. Plexuses. — We have already seen that in many regions of the body, especially about the neck, loins, and pelvis, adjacent nerves interlace to form a network, or *nervous plexus*. Nerves passing outward from a plexus contain fibers from several different nerves, and the parts to which these nerves are distributed are thus sometimes brought into connection with a considerable part of the central nervous system. The nerves which supply the limbs, where very complex muscular movements are required, and where nervous coördination of those movements is necessary, come from large plexuses where fibers from many nerves are intermingled. (It should be remembered that the term "network" is here used subject to the limitation given above [p. 279] and does not imply more than is there stated.)

By means of the spinal nerves nearly all the nervous impulses from the trunk and limbs pass through the spinal cord to the brain.

419. Membranes of the Brain and Spinal Cord. — Three membranes inclose the brain and spinal cord. The *dura mater* is a tough, white fibrous and elastic membrane lining the bony cavity of the skull which contains the brain, and the vertebral canal in which lies the spinal cord. It also lies in folds between the divisions of the brain.

The *arachnoid* is a thin membrane of loose connective tissue, forming a sort of closed sac (like the pericardium), which secretes a serous fluid. It lies between the dura mater and the pia mater.

The *pia mater* is an extremely delicate, highly vascular membrane (that is, having many blood vessels), closely investing the nervous matter of the spinal cord and the brain. It follows all the curves and convolutions of the brain, and carries to all its parts and to the spinal cord

numerous blood vessels which assist in their nutrition. The three membranes are sometimes called the ***cerebro-spinal meninges***, and the serious disease called ***cerebro-spinal meningitis*** is due to inflammation of these lining membranes.

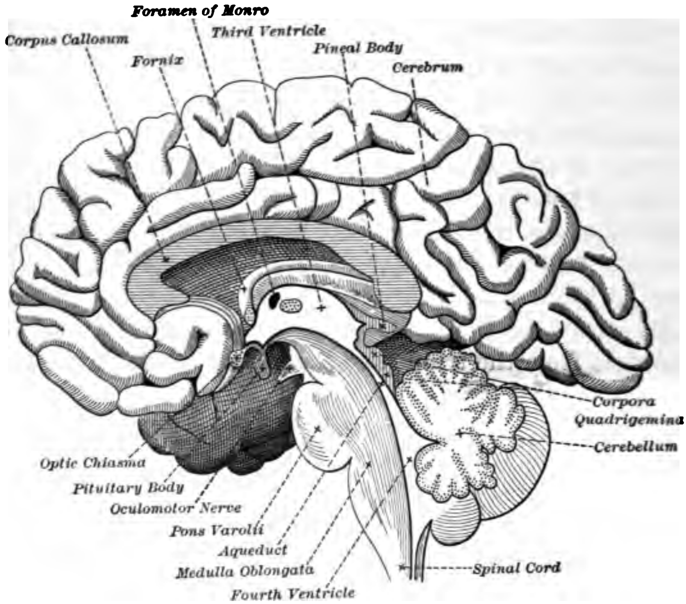

Fig. 129. — The right half of a vertical median section of the brain.

420. The Brain (Figs. 129, 130, 131, and 134). — The division of the brain into five principal parts is derived from the manner of the development of those parts from certain primary divisions of the embryo. Those parts are : (1) the *cerebrum*, with its two hemispheres ; (2) the *optic thalami ;* (3) the *corpora quadrigemina*, or *optic lobes*, with the *crura cerebri ;* (4) the *cerebellum* and *pons Varolii ;*

and finally (5) the *medulla oblongata*. More minute divisions might be and often are given, but these are sufficient for the present purpose.

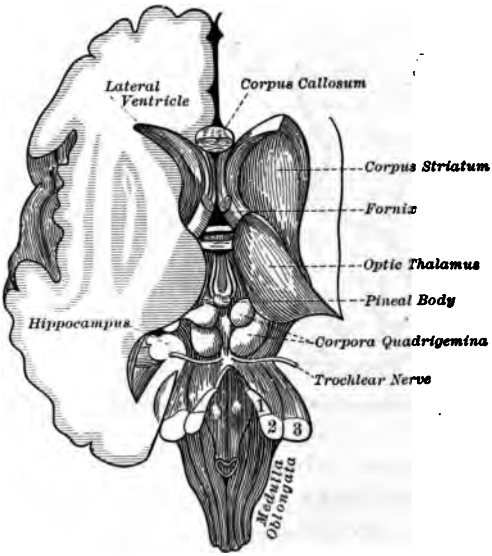

Fig. 130. — Brain viewed from above, with the cerebellum and a large part of the cerebrum removed, exposing the structures hidden by the cerebrum.

1, 2, 3 cut surfaces of the peduncles of the cerebellum.

421. The Cerebrum (Fig. 131). — More than two thirds of the whole weight of the brain belongs to the two hemispheres of the *cerebrum*. Its surface of gray matter, called the *cortex*, presents a characteristic folded appearance, the convolutions being separated by *fissures*. The deeper fissures divide each hemisphere into five lobes, called, from their locations in the cranium, the *frontal*, *parietal*, *temporal*, *occipital*, and *central lobes*, the last being also called the *insula* or *island of Reil*. The *insula* is not

visible from the surface, but lies deep within the ***Sylvian fissure***, which divides the frontal from the temporal lobe, and is concealed by the convolutions of the upper lobes

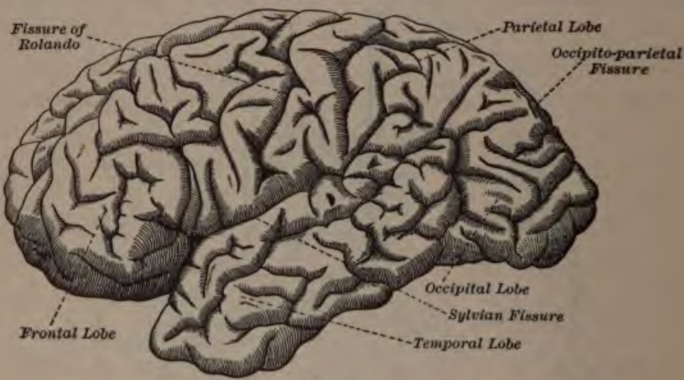

Fig. 131. — Side view of the left cerebral hemisphere.

(Fig. 132). Other principal fissures are the deep longitudinal one separating the hemispheres; the ***fissure of Rolando***, which lies between the frontal and parietal lobes; and the ***occipito-parietal fissure***, separating the parietal from the occipital lobe. A broad band of white nerve fibers, the ***corpus callosum***, connects the two hemispheres (Fig. 129). In the base of each frontal lobe is a bulbous expansion of gray and white matter connected by a stalk, or peduncle, called the ***olfactory tract***, with the mass of the hemisphere. These are the ***olfactory bulbs***,

Fig. 132. — Side view of brain with temporal lobe cut away so as to expose the underlying insula.

with which are connected the olfactory nerves (Fig. 134). They are direct outgrowths of the brain substance. Lying partly in the lateral ventricles (§ 426) and partly embedded in white substance of the hemispheres, are the pear-shaped *corpora striata* (Fig. 130), composed of white and gray matter. They are ganglia on the path of motor nerves.

422. The Optic Thalami are masses of gray matter in the base of the cerebrum (Fig. 130), and are closely connected with the corpora striata, which belong to the cerebrum. These two pairs of gray bodies are often called the *basal ganglia*. From them nerve fibers radiate into the convolutions of the cerebral hemispheres. The optic thalami are ganglia on the path of sensory nerves; the corpora striata belong to the motor tract.

423. The Corpora Quadrigemina, or Optic Lobes, and the Crura Cerebri.—The *corpora quadrigemina*, or *optic lobes*, lie behind and between the optic thalami (Figs. 129 and 130). They are masses of gray matter, or rather a single body divided by shallow fissures into four hemispherical parts. The optic tracts arise superficially from their surfaces. The optic lobes rest upon the hinder face of the *crura cerebri*. These latter are bundles of nerve fibers forming peduncles, or stalks, which connect the cerebrum with other parts of the brain.

424. The Cerebellum and Pons Varolii (Figs. 129 and 134).—The *cerebellum* is composed of gray and white matter, and lies in two hemispheres across the back of the cerebro-spinal axis. The hemispheres are connected by bands of white matter, called peduncles, with each other and with other parts of the brain. The white matter of the cerebellum is arranged on each side in a central trunk, which divides into many branches, around which the gray matter is placed, the whole forming what is called, from

its likeness to a branching tree, "the tree of life." The gray surface is arranged in parallel ridges, or laminated folds, differing from the irregular convolutions of the cerebrum.

The *pons Varolii* also contains white and gray matter. In it white fibers pass upward to connect the *medulla oblongata* with other parts of the brain. It contains, also, the strands of white matter which form the middle peduncle of the cerebellum. The *pons* is, therefore, as its name implies, the passage, or bridge, by means of which connection is made between all parts of the nervous system.

425. The Medulla Oblongata, or Spinal Bulb, is the enlarged upper portion of the spinal cord contained within the cavity of the cranium (Figs. 129, 130, and 134). It is conical in shape, about one inch in thickness at its broadest part, and about one inch and a quarter in length, and consists of two symmetrical halves. On the forward, or anterior, surface is seen a deep groove, which is a continuation of the anterior fissure of the cord. A similar but more shallow fissure forms the posterior division between the halves. Just as the cord begins to expand into the medulla, many of the fibers which compose the lateral columns of the cord cross from one side to the other. These bundles of white fibers are called, in the medulla, the *pyramids*, and their crossing is called the *decussation of the pyramids*. Other fibers of the pyramidal tracts cross lower down at different levels in the cord. In general, a rearrangement of the fibers of the cord takes place in the medulla. What it is especially important to notice is that each tract of fibers in the cord has connection through the medulla with the centers in *both* the cerebellum and the cerebrum.

The gray matter of the medulla oblongata is partly continuous with that of the cord, but is partly broken up into independent groups of cells, or nuclei, which are the *deep origins* of most of the cranial nerves.

426. The Ventricles of the Brain, and the Cerebro-spinal Fluid. — The *ventricles* are irregular cavities in the brain, communicating with one another and continuous with the canal of the spinal cord (Fig. 133). The *lateral ventricles* lie one in each hemisphere of the cerebrum. They open into the *third ventricle*, which is in the middle line. A narrow canal, called the *aqueduct of Sylvius*, connects the third with the *fourth ventricle*, of which the back of the pons and the medulla oblongata form the floor, while the overhanging cerebellum forms part of its roof. A small opening in the pia mater, which completes the roof of the fourth ventricle, makes connection between these interior cavities and the external surface of brain and cord, so that the fluid which fills the space beneath the arachnoid is continuous with that in the inside.

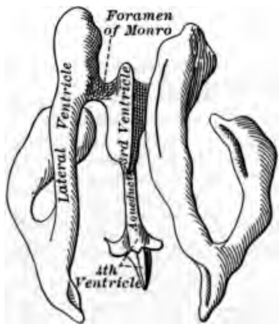

Fig. 133. — Cast of brain cavities.

The *cerebro-spinal fluid* is a thin, watery substance which bathes the external surfaces of the brain and spinal cord, and fills the ventricles and the spinal canal.

427. The Cranial, or Cerebral, Nerves (Figs. 134 and 135). — Of the twelve pairs of nerves issuing from the brain, ten have their deep origins in the floor of the fourth ventricle or in adjacent gray matter. Each cranial nerve is said to have a *deep origin*, which is that portion of gray

matter where its fibers rise from nerve cells, and a *superficial origin*, which is the region of the brain surface from which the nerve, as a nerve, departs upon its mission.

1. The first pair of cranial nerves are the *olfactory nerves*, distributed directly and wholly to the organ of smell, and sensory in function.

Fig. 134.—Ventral (anterior) surface of the brain.

2. The *optic nerves* go to the organs of sight. From their deep origins to the point where a part of their fibers cross they are called the *optic tracts*. They are sensory.

3. The *oculomotor* nerve supplies all the muscles of the eyeball except the superior oblique and external rectus,

and communicates with a nerve plexus of the sympathetic system.

4. The *trochlear*, the smallest of the cranial nerves, is motor. It supplies the superior oblique muscle of the eye, and communicates with the same plexus as does the third nerve.

5. The *trigeminal*, the largest cranial nerve, is mixed in function. Its motor division goes to the muscles of mastication. The larger division is the great sensory nerve of the face and head.

6. The *abducens* supplies the external rectus muscle of the eyeball as its motor nerve.

7. The *facial* is the great motor nerve of the muscles of the face. One of its branches, the *chorda tympani*, passes across the tympanum and joins the lingual branch of the fifth nerve. It is purely motor.

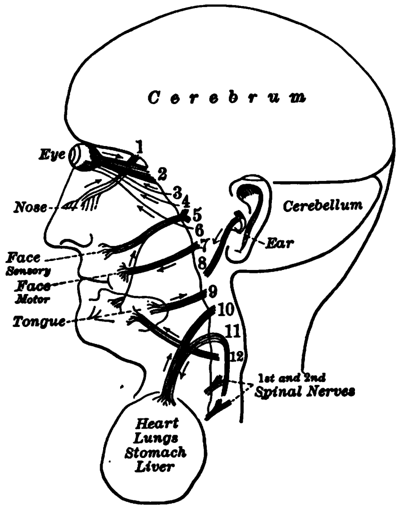

Fig. 135. — Diagram of the distribution of the cranial nerves.

8. The *auditory*, a sensory nerve, leaves the surface of the brain in two roots: one, the *cochlear branch*, is the auditory nerve proper, and goes to the cochlea; the *vestibular branch* ends in the semicircular canals, the utricle, and the saccule.

9. The *glossopharyngeal*, after communicating with several neighboring nerves and ganglia, separates into

two main divisions. One goes to the pharynx, the Eustachian tube, the palate, and the tonsils, as a motor nerve chiefly. The other is the nerve of taste for the back part of the tongue.

10. The *vagus*, or *pneumogastric*, is the wandering nerve. It is longer and has a more complicated distribution than any other cranial nerve. It sends branches to pharynx, larynx, esophagus, stomach, intestines, lungs, heart, liver, and spleen. It is both sensory and motor.

11. The *spinal accessory*, a purely motor nerve, contains fibers from a nervous center in the walls of the fourth ventricle, and from the anterior horns of the spinal cord. The latter fibers pass up into the cranium and join the cerebral fibers of this nerve just before it passes out of the skull. The nerve has two branches, one of which joins the vagus, to which it supplies motor fibers and inhibitory fibers for the heart, while the other supplies certain muscles of the shoulder blade and neck.

12. The *hypoglossal* is connected with the vagus, with a ganglion of the sympathetic system, and with some of the upper spinal nerves. It is the motor nerve for the muscles connected with the hyoid bone and the tongue, and sends a branch to some muscles of the neck and chest. It also contains vasomotor filaments.

428. The Nervous End Organs have been described in previous chapters, and are mentioned here to complete the anatomical view of the nervous system. They are in man of three classes, viz. *end plates* of different forms found in the muscles, *organs of special sensation*, and *secreting cells* found in the various glands.

429. The Sympathetic System (Fig. 136). — What is commonly called the *sympathetic* or *ganglionic system* consists of a double chain of ganglia, twenty-four upon each

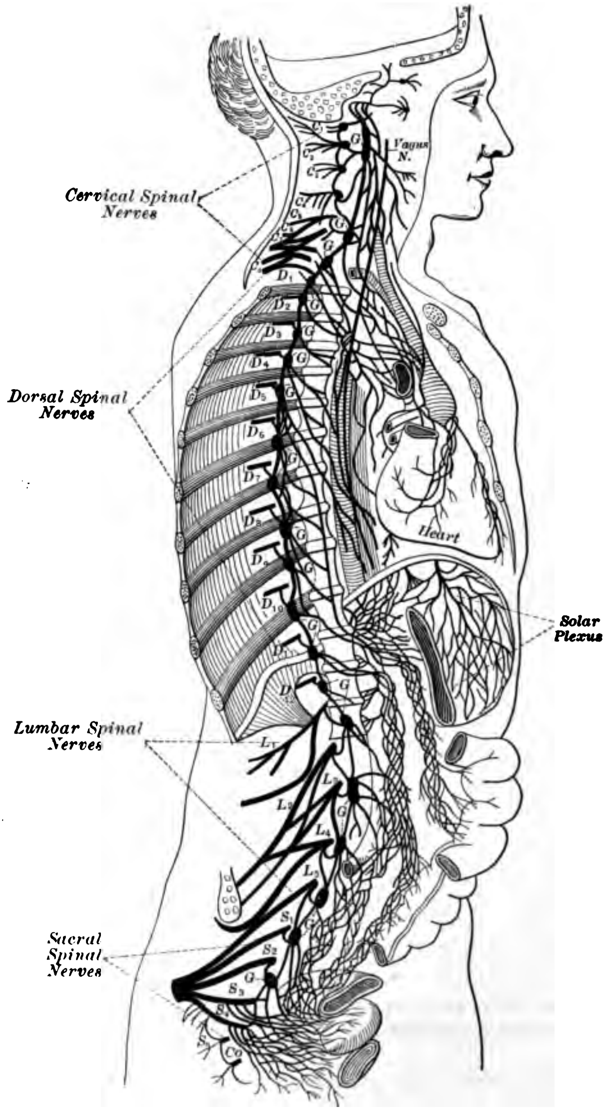

Fig. 136. — Diagram of the sympathetic nervous system.
G ganglion chain. *Co* coccygeal spinal nerve.

side, lying along the whole length of the spine. They are connected by white fibers with the spinal cord, with one another by gray or nonmedullated fibers, and with the spinal nerves by both white and gray fibers. At their upper extremities, and in other situations also, the great sympathetic nerve trunks come into connection with all the cranial nerves except the olfactory, auditory, and optic.

The gray fibers issuing from the ganglia are usually too minute to be visible to the naked eye, and they are much more numerous than those received by the ganglia from the central system. Most of these gray fibers seem to convey efferent impulses to the tissues, though some are afferent, carrying impulses from the viscera to the central system. But a certain number of the fibers from the main sympathetic chain turn back from the ganglion toward the center, some to reach the membranes of the spinal cord, some to follow the course of the principal branch of the spinal nerve which is distributed to the skeletal muscles and the skin. Nervous connection is thus established between all these various parts. In their distribution the sympathetic nerves follow closely the course of the blood vessels, around which they form

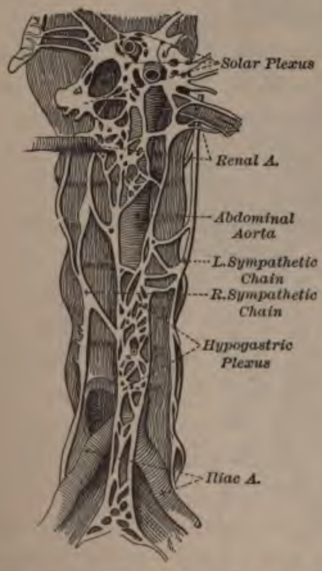

Fig. 137. — The solar and hypogastric sympathetic plexuses.

plexuses, fibers from which accompany the blood vessels throughout the body, penetrating to all parts of the various organs. In the abdomen is found also a great plexus of nerve fiber called the *solar plexus*, because smaller plexuses radiate from it like rays of light from the sun (Fig. 137). From the solar plexus nerve filaments are distributed to all the abdominal organs.

Demonstration

125. *Dissection of the Brain.* — The specimens used in Ex. 6 (p. 33) should now be studied more in detail. The brain should be divided into two symmetrical halves, and the longitudinal median section, thus exposed, should be compared with Fig. 129. In this way all the parts of special importance can be identified. Care should be taken that the pupil makes this careful detailed comparison and identification. Slice away the dorsal (upper) surface of the cerebrum till a cavity, the *lateral ventricle*, is reached. By carefully removing the roof of this cavity the latter is seen to extend forward and downward as the *anterior cornu*, and downward and backward as the *descending cornu*. The *corpus striatum* is an oval mass projecting into the cavity of the anterior cornu. The *hippocampus* is an oval projection forming the floor of the posterior part of the lateral ventricle, including the descending cornu. Between the corpus striatum and the hippocampus extends a fibrous band, *the descending pillars of the fornix*. This band can be traced to the middle line and seen to be a part of the fornix cut in the median section. Cut away the hippocampus and the band of the fornix; the *optic thalamus* is exposed (see Fig. 130). Posterior to the thalamus are the two *corpora quadrigemina* of that half of the brain. Between the descending pillars of the fornix and the optic thalamus is a narrow opening, the *foramen of Munro*, which communicates with the third ventricle and through the latter with its fellow of the opposite half of the brain. By this means the two lateral ventricles communicate with each other and with the other cavities of the brain.

The cerebellum will be found on close examination to be attached to the rest of the brain by three pairs of fibrous bands. One pair,

the *superior peduncles*, connect the cerebellum with the corpora quadrigemina; a second, the *middle peduncles*, form the lateral extensions of the pons Varolii; the third, *inferior peduncles*, connect with the spinal cord. By severing the connections of the cerebellum the cut ends of these peduncles may be seen. Other parts of the brain can be identified by comparing with the illustrations of the human brain given in the general text.

If the brain has been carefully removed from the skull, the twelve pairs of cranial nerves can be identified by careful dissection and by comparison with the figures of the human brain.

CHAPTER XXII

FUNCTIONS OF THE NERVOUS SYSTEM

430. In a broad sense, the functions of the nervous system may be said to be to bring its possessor into due relation with the universe of which he is a part, and to enable him to live that life to which his organism is adapted; to supply channels of communication between all parts of the body; to supervise, direct, and control all the conscious and unconscious activities of the organism. More specifically they are, in the case of man, sensations, general and special; regulation of all motion; control of all vital processes; and the manifestation of mental operations, — thought, will, and emotion.

431. Sources of Knowledge. — We have two sources of information respecting the action of the various parts of the nervous system. There is, first, observation upon human subjects. Obviously few experiments can be made upon man himself, but by careful study of man in health and of symptoms shown in diseases which affect the brain and nerves, much has been discovered. The second source of knowledge is from experiments upon animals. Electrical stimulation acts upon the nerves much as does the natural nervous stimulus, and by its use in the physiological laboratory, and by the destruction of one part or another of the nervous system of an animal, the paths of transmission of impulses and the functions of the different parts

have been gradually made out. While our knowledge of the functions of the nervous system has thus been greatly extended, especially during recent years, it is probable that a much larger field still remains only partly explored, and there is reason to expect that a much more accurate and definite acquaintance with this most important portion of the human organism will soon become possible.

432. Functions of the Nerves. — The nerves are the telegraph wires of the system. They transmit impulses from all parts of the body to the central nervous system and from the central system to all parts of the body. Individual nerve fibers transmit impulses in only one direction.

433. Afferent and Efferent Nerves. — Nerves or nerve fibers which carry nervous impulses *to* the centers are *afferent;* those which carry impulses *from* the centers are *efferent.* The first are generally called ***sensory;*** but impulses which do not result in sensation, that is, which do not affect consciousness, may be conveyed by afferent nerves. The spinal cord may be cut or injured so that its lower portion and the nerves issuing from it have no connection with the brain. Still if the foot is pricked or tickled, the afferent nerves carry the impulse to the cord, efferent nerves bring back a motor impulse, and the foot is drawn back, all without conscious sensation.

434. Classification of Nerves. — *Afferent* ***nerves*** have been classed in two groups.

1. Nerves of special sense, viz. of sight, hearing, touch, taste, and smell.

2. Nerves of general sensibility. These convey to the brain those vague, indescribable feelings of comfort and general well-being, or of discomfort, languor, and weariness, which come from the interior of the body.

Excessive stimulation of any of these nerves results in *pain.*

435. *Efferent Nerves* carry impulses of many kinds besides those of motion. Five classes of these nerves in the human system have been described: —

1. *Motor* nerves, distributed to the voluntary and involuntary muscles, and carrying impulses resulting in movement.

2. *Accelerator* nerves, which increase the rate of rhythmical action, as in the heart.

3. *Inhibitory* nerves, which retard or wholly check rhythmical action, as in certain nerve fibers of the heart.

4. *Secretory* nerves, which convey from the central system to the glands impulses resulting in the secretion of their special products.

5. *Trophic* (from a Greek word meaning "nursing") nerves, which control the nutrition of the parts to which they go.

Still other nerves exist which can be classed neither as afferent nor efferent. They are those which connect different parts of the brain and cord with one another, and in general form lines of communication between nerve centers. They have been called *intracentral nerves.*

436. **The Nervous Discharge.** — When a nervous impulse reaches a nerve cell, a remarkable change takes place. Something similar to an explosion occurs, and a new, different, and more powerful current issues from the cell. An afferent impulse arrives at a nerve center; that change which is called the *nervous discharge* takes place; energy is set free which is conducted by efferent fibers to the terminal plate in a muscle fiber, it may be. Here again a second nervous discharge results, and a still larger amount of force is liberated.

437. Functions of the Spinal Cord. — A nerve center is a group of nerve cells which join together in some particular form of nervous action. The gray matter of the spinal cord is a series of nerve centers, while the white matter is arranged in bundles of nerve fibers whose function is, like that of the nerves themselves, the transmission of impulses.

Two sets of functions belong to the spinal cord. It is the channel by which volitions of the brain are conveyed to many of the muscles, and the channel by which many sensory impulses reach the brain; that is, by means of the cord voluntary action takes place, and by means of it sensory impulses are transmitted.

Another set of functions belonging to both the spinal cord and the brain is the production of *reflex action*. Some writers upon physiology maintain that all nervous action is, in the final analysis, reflex, and due, more or less remotely, to external stimulus, what is called mind not being able to originate any nervous impulses whatever. Others support the opposite view, that all nervous action is voluntary in the beginning, and becomes reflex by practice, either on the part of the individual, or on that of previous generations of ancestors, by whom the tendency to act in certain ways has been transmitted to their descendants. This is not the place for a discussion of such a question, and we may accept the usual distinction between voluntary and reflex action, the latter being invariably the result of an impression received from without.

438. Reflex Action. — By reference to Figs. 48 and 52, on pp. 72 and 90, the course of a nervous impulse in reflex action may be traced. A nerve is stimulated at the surface, the impulse is conveyed by the afferent

sensory fibers of the nerve through the posterior root to the spinal cord. There it may pass up to the brain (Fig. 52) in one of the white columns of the cord, and, affecting certain cells in the cortex, result in consciousness and sensation, followed by voluntary motion. Or it may reach directly certain cells in the posterior horn of gray matter in the cord, and be thence transmitted by communicating fibers across to other cells in the anterior horn, from which a motor impulse is sent forth to certain muscles, and they are called into action. By this shorter path motion takes place without necessarily affecting consciousness, and without the interference of the brain; that is, the nerve cells in the cord which receive the stimulus reflect the impulse to other cells of the cord, which then issue motor orders, without waiting for instructions from the overruling brain. It is as if the captain of a company of soldiers in a great army, having received from incoming scouts news of an attack by hostile forces, immediately orders his men, without waiting for orders from his superior officers, to turn upon the enemy and repulse them.

The medulla oblongata is also a great reflex center, very many afferent-efferent circuits being completed there without affecting the higher cerebral centers.

439. Examples of Reflex Action. — If a sudden flash of light strikes the eyes, the lids are immediately closed. Any part of the body touching a hot object is at once drawn back. A person in sleep may raise his hand to brush away a fly from his face, or he may start at a sudden noise whether awake or asleep. All these acts may take place without conscious orders from the brain. Many of the vital processes are wholly or mainly reflex acts. Of most of them we are, in health, wholly unconscious.

The spinal cord centers, or those of the medulla, send efferent impulses to the glands that they may secrete the digestive juices, when afferent impulses have been excited by food taken into the mouth or the stomach. The muscular movements of the alimentary canal, called peristalsis, are reflex. So are the contraction and dilation of the blood vessels in response to sensations of temperature conveyed by afferent nerves to the reflex centers. The growth of the cells throughout the body is also presided over by these centers.

The muscular movement of reflex action is often greatly out of proportion to the strength of the stimulus received. A slight irritation of the mucous membrane of the trachea may result in a fit of coughing so violent as to bring into action most of the muscles of the trunk and limbs. The mere prick of a pin may cause a man to bound from his chair and execute a series of movements involving hundreds of muscles. It is as if the nervous irritation which is brought by an afferent nerve to one of the nerve centers *overflowed* the cells and fibers of that segment and stimulated neighboring centers also.

440. Voluntary Movements may become Reflex. — When a child begins to learn to walk, each separate movement is slowly and carefully directed by the intelligence of the brain. In time, however, the brain is relieved by the spinal cord of nearly all attention to the locomotion of the body, and action which was once voluntary is better done under control of the reflex centers. If we undertake to descend a stairway rapidly, watching and directing each step by the will, we are far more likely to make a misstep and fall than if we pay no attention to the separate movements required. So in performing upon musical instruments, in writing with a pen or a typewriter, or in riding

a bicycle, the movements at first slow and toilsome become rapid and unconscious as well as more accurate by practice, which places them under the direction of the spinal cord instead of the brain. They become, as we say, "automatic," instead of voluntary.

441. Advantages of Reflex Action. — By this provision for independent action in the spinal nerve centers the brain is relieved of a great amount of labor, and so given leisure for the more important energies of life. Then, as the spinal cord can act more promptly than the brain, it is better able to protect us from sudden injury. If we had to wait till the brain ordered the muscles of the arm to pull the hand out of the fire, we might often be seriously burned.

A thorough education of the spinal cord in respect to a wide variety of reflex movements greatly extends a man's useful and enjoyable activities.

442. Voluntary Control of Reflex Action. — Although what are called reflex actions take place largely without the interference of the will, it does not follow that any distinct arbitrary line of demarkation can be drawn between reflex and voluntary acts. In playing the piano, for instance, the rapid and complex movements required are to a certain extent voluntary as well as reflex, though the cells of the nerve centers discharge without waiting for the reception of orders from the brain. In respect to a large number of reflex acts the will is able to exercise a restraining influence if not entire inhibition, and such overruling power constitutes *self-control.* A child may, by reflex action, utter piercing screams at sight of what he judges to be a dangerous object, and may even be thrown into convulsions by terror; but when he has become a man — if he has received proper

training — he will have acquired voluntary control over his muscles, the scream will be restrained, and his muscles will remain quiet, or will remove him from the dangerous spot according to the direction of his brain. Many a soldier has thrown down his gun and beat an inglorious retreat from the scene of his first battle, and yet has afterward become the honored veteran of many a hard-fought field. A child may roar with pain and clutch with all his strength at the dentist's hand when his first tooth is drawn, while men have been known to endure the amputation of a limb without flinching. Important as it is to educate the reflex nervous centers to the supervision of swift and accurate useful movements, it is of even more importance that the brain should still be able to exercise a superior restraining power when needful in respect to even those acts which may be ordinarily left to the reflex centers.

443. Functions of the Sympathetic System. — Experiments have shown the functions of the sympathetic system to be threefold.

(1) This system has control of the contractile coats of the blood vessels. Certain fibers, called "vasoconstrictors," carry impulses by which the tone of the walls of arteries and veins is maintained. If the sympathetic nerve is divided in the neck, there is a general dilation of the blood vessels on the same side, and a fall of blood pressure in the arteries. Other fibers, called "vasodilators," seem to possess the power of *inhibiting* the action of the "constrictors," and so causing dilation of the vessels. A large part of the action of the vital organs is controlled by these vasomotor nerve fibers which regulate the amount of blood distributed to those organs.

(2) Other fibers of the sympathetic nerves seem to stimulate directly the activity of secreting cells in the glands.

(3) Still other fibers regulate the peristaltic action of stomach and intestines, and so influence digestion, while others influence, to some extent, the process of respiration.

The sympathetic nerves affect directly only *involuntary processes.*

444. Functions of the Medulla Oblongata. — The whole of the brain above the medulla may be removed from an animal without killing it. Regular and rhythmical respiration will go on, the heart will still beat, and the blood will circulate, while reflex action will continue, and many muscles will contract when the sensory nerves connected with them are irritated. Still more complex movements may take place. If food is placed on the back of the tongue, the numerous muscles concerned in swallowing will be excited and will act with their usual accuracy. It is plain that all these reflex movements must be coördinated in the medulla and the lower centers. An animal living thus, by the action of the nervous centers connected only with the spinal cord and the medulla, will exist by means of purely reflex mechanism without sensation and without intelligence.

But let the medulla be destroyed; respiration will cease (except in the case of the frog, which continues to breathe by cutaneous respiration), and death will almost instantly follow. The nervous center to which is committed the coördination of respiratory movement has been located at the angle of the wall of the fourth ventricle, and that point has been called the *vital knot.* The medulla may be divided above the respiratory center, and the action of the muscles of the chest and diaphragm will be unaffected. Though the heart, as has been stated, will continue its rhythmic beat for a time after all connection with cerebro-spinal centers has been severed, still

its movements are much modified through its nervou communication with the medulla. Inhibitory fibers pass from there in the vagus nerve, and if that is cut th heart's motion is accelerated. Accelerator fibers from the medulla pass to the heart through the spinal cord and the sympathetic nerves. Their destruction or severance from the center in the medulla slows the heart's beat. The *medulla oblongata*, then, is *a coördinating center for those reflex actions upon which the maintenance of life depends.*

445. Besides its great function as a center for the reflex action connected with the vital processes, the medulla oblongata also acts, like the cord, as a conductor of sensory and motor impressions. Motor fibers from the upper parts of the brain cross in the anterior pyramids of the medulla and descend the cord, to pass out in the anterior roots of spinal nerves. If they are destroyed on the right side above the crossing, paralysis of motion o the left side results; while section of the fibers on the right side below the crossing will cause paralysis on the right side.

446. Functions of the Pons Varolii. — The pons, beside serving as a passageway for afferent and efferent impulse between the medulla and other parts of the brain, contain imbedded in the bundles of white fibers a number o nuclei of gray matter connected with the roots of cranial nerves, some of the same nerves being also connected with nuclei in the medulla. The pons is to be regarded as both a conductor and a reflex center, and also as relay center between the cerebellum and the cerebrum.

447. Functions of the Cerebellum. — The cerebellum re ceives impressions through its three pairs of peduncle by which its hemispheres are connected with other part of the brain, and so with the spinal cord, and with eacl

other. It has long been regarded as established that its special function is to act as a *center* — not the sole, but the great center —*for coördination of muscular movement*, and especially for that coördination of muscles necessary to maintain the body in a position of equilibrium. This harmonious adjustment of the working of so large a number of muscles requires the action of a large and complicated nervous mechanism, involving the eyes, portions of the auditory apparatus, and the apparatus for touch, as well as the muscular sense which tells us what we are doing with our muscles. Sensory impulses from these four sources reach the cerebellum by its peduncles and keep it informed as to the position of the body in space. Then, in order that all the numerous muscles involved may act with regulated strength and in mutual harmony to preserve the equilibrium, the nerve centers in each half of the cerebellum send on afferent impulses to the cerebral hemisphere of the opposite side. There takes place the motor discharge which sends forth the efferent impulse to the muscles. In the process of selecting the muscles which are to act, and arranging the order and amount of their action, the gray matter of the higher centers, of the basal ganglia, the cerebellum, and the whole of the spinal cord is concerned.

The cerebellum is also especially involved in the production of the finer and more delicate movements of the hand.

448. Functions of the Corpora Quadrigemina and the Crura Cerebri.— Of the functions of the *crura cerebri*, or peduncles of the cerebrum, we know little except that they conduct nervous impulses. If one peduncle is destroyed, the animal moves toward the opposite side, round and round in circles. The *corpora quadrigemina*, or *optic lobes*, are the

first portions of the brain to receive visual impressions through the optic tracts; but just what share they have in vision is still not fully determined. We know that they are concerned in the movements of the iris and of the ciliary muscle, and there are indications that they have much to do with the consciousness of light and color. It may be that these and other neighboring ganglia, having received direct impressions from the retina, originate reflex movements without waiting for voluntary, conscious action of the higher centers. This would explain the unconscious sight and movements of the somnambulist, who sees, without knowing it, how to direct his steps along dangerous and intricate paths. Destruction of the corpora quadrigemina causes immediate blindness.

449. **Functions of the Optic Thalami.** — The ganglia of the *optic thalami* also have something to do with sight, as serious injury to them invariably results in disturbance or destruction of vision. There is also evidence that they play a subordinate part in connection with sensation, and, with the *corpora striata* and conducting fibers, establish a shorter afferent-efferent circle which does not involve the higher centers of the brain, but whose action results in consciousness and volition.

450. **Functions of the Cerebrum.** — If a frog be entirely deprived of the cerebral hemispheres and left quite undisturbed, it will sit quietly in the same spot forever. Though it breathes, it will be an insensible, immovable lump of matter. It may be surrounded by food, but it will die of starvation. No spontaneous movement is possible to it. But let the frog be touched, and it will move. If gently stroked, it will croak. If its foot be pinched, it will hop. If thrown into water, it will swim to land. A sudden movement close to its eyes will cause it to draw back.

A fish under similar conditions will continue to swim in a straight line unless obstacles appear, and those it will avoid as usual. Its movement will be kept up until ended by exhaustion. It will never pause to eat, though abundance is on every side. Like the frog, the fish deprived of its cerebrum is incapable of any action not the result of immediate and direct external stimulus. It swims because the contact of the water with the surface furnishes constant irritation to the swimming mechanism. Corresponding results follow experiments upon higher animals and observations upon man himself. The lower nerve centers act at once in response to present stimulus, and act without necessarily affecting consciousness, without sensation, and without will.

451. The frog or the fish retaining the whole of the brain intact responds to external irritation, but the precise results of such irritation cannot be accurately predicted, and the action may be deferred for a longer time than when the cerebrum is wanting.

In the higher animals the varieties of possible results of stimulation are still more numerous. Strike a wild cat over the nose with a club and he may turn and flee, or he may plunge forward and bury his teeth in your body. The nervous discharge in all these cases will, however, be likely to take place with considerable promptness in one way or another.

But suppose a man to receive a severe injury or insult. He may retaliate at once by shooting or knocking down his assailant, or he may cherish a sense of wrong for many years, seeking opportunity for revenge. He may even inculcate the enmity upon the minds of his children, to be passed on from generation to generation as a family feud. In man, therefore, and to some extent in the higher ani-

mals also, we find the singular power of postponing, often for an indefinite time, the reaction which in the lower animals immediately follows stimulation. Because it is impossible to trace all nervous reaction to an incoming impulse, we must not thence conclude that none has been received. To the higher cerebral centers alone, that is, to the gray matter of the cortex, belongs this power of *deferred action*. They are able to postpone the nervous discharge which results from incoming impressions until those impressions have been, as we may say, *considered*. The nature and meaning of the efferent impulse to be issued in consequence of the impulse received may then be decided upon after long deliberation and in view of very remote sensations.

452. The *cerebrum*, then, is the seat of those psychic or mental processes which are called *consciousness*, *perception*, *volition*, *memory*, *thought*, *imagination*, and *emotion*. These are all terms which in the present state of knowledge belong rather to psychology than to physiology. They have an undeniable physical basis, but to what extent they depend upon material facts and physical laws, we do not know. *Consciousness* may be said to be the knowledge which the mind has of its own operations and conditions. Physiologically speaking, it has been called "the final phase of sensory impressions." *Perception* is the recognition by the mind of impressions received through sensory nervous tracts. *Volition*, so far as it is physiological, is the impulse in the cerebral hemispheres which originates motor activity. *Memory* may be called the power of storing up nervous impressions and making them at some indefinite later period the cause of efferent influences. Perhaps we need not go further in the attempt to give physiological definitions to metaphysical terms.

453. Localization of Functions in the Cortex. — The area of the cortex, with all its convolutions, is in man about four square feet. In the lowest vertebrate animals the surface of the brain is smooth, but as animals rise in the scale of intelligence fissures and folds appear, growing more complex and more like those of man, till in the brain of the highest apes a striking resemblance is seen to that of man.

The whole surface of the human cortex has now been mapped out into tracts, or districts, to many of which it is found that special functions are assigned. Post-mortem examination of diseased human brains, together with close study of the effects of disease during life, and numerous experiments by vivisection upon animals, — especially upon the monkey as possessed of a brain of the same type as that of man, — have resulted in greatly extending our knowledge respecting this localization of functions in the cortex. We cannot follow the method and progress of discovery, but some of the conclusions have been referred to in preceding chapters and others may be mentioned here.

In respect to some of the highest mental operations the brain probably acts as a whole through the immense number of associational fibers connecting all parts of the cortex, so that no physiologist is able to say that thought is located in certain cells of that convolution, or memory or imagination in another. But it is still correct to say that certain groups of cortical cells are concerned in a peculiar way with certain sensations or with certain movements.

454. Motor Areas. — It has been found that when the surface of an animal's brain is laid bare and an electric current is applied to the convolutions, the stimulation of

the same spot in the cortex is always followed by the same movement in the same animal. Those portions of the cortex, therefore, whose stimulation results in motion, are called *motor areas*. Speaking generally, these motor areas may be said to occupy the portion of the cortex about the fissure of Rolando and along the middle surface, or edge, of the hemispheres. Particular movements of head, trunk, and limbs are associated with particular spots in the surface of this region, as shown in Fig. 138. The area controlling articulate speech, that is, the movements

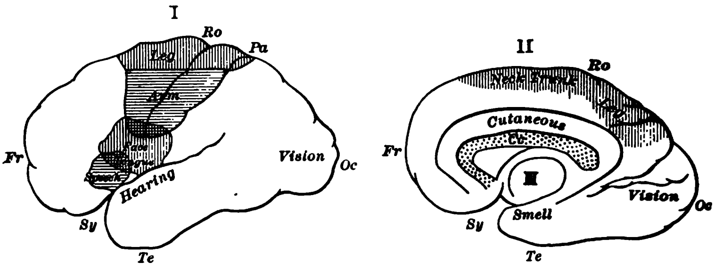

Fig. 138. — Diagrams illustrating localization of function in the cerebrum.

I outer surface of left hemisphere.
II inner surface of right hemisphere.
Motor areas are shaded.
Cc corpus callosum.
Fr frontal lobe.
Oc occipital lobe.
Pa parietal lobe.
Ro fissure of Rolando.
Sy Sylvian fissure.
Te temporal lobe.

of tongue, lips, etc., in speech, lies adjacent to the Sylvian fissure on the lowest frontal convolution. And, what is peculiar to this cortical area for speech, it appears to be confined to a single hemisphere — in most cases the left — instead of being bilateral as are other parts of the brain.

455. Sensory Areas in the cortex are less definitely located than are the motor areas. Broadly speaking, they lie behind the motor surfaces.

The *area for vision* is in the occipital lobe. If this area be diseased, blindness of half of each retina on the same side results.

The *auditory area* is believed to lie in the upper portion of the temporal lobe; the *areas for taste and smell* on the under and inner side of the same lobe. *Tactile sensations* have been located in certain portions of the under surface of the occipital lobe; but most recent experiments indicate that some, at least, of the sensory fibers end in what has been called the motor area about the fissure of Rolando. If that is established, it will appear that the fibers connected with conscious sensation are in close association with those which convey voluntary motor impulses, and the Rolandic area will be more properly termed the *sensori-motor area.*

456. It will be noticed that in the map of the cortex a large portion of the front of the brain remains, like great tracts of land in Central Africa upon old geographical maps, without names and internal divisions. They are unexplored or, at least, unknown regions. No specific functions can be positively assigned to those frontal convolutions of the cerebrum. An animal deprived of them appears to suffer little inconvenience in consequence, and in one well-known case where a man lost the frontal portion of his brain in an explosion of dynamite, full recovery followed without any permanent noteworthy consequences. It is a favorite theory with some that the frontal convolutions are the seat of the intellectual faculties, but the theory has not been confirmed.

CHAPTER XXIII

HYGIENE OF THE NERVOUS SYSTEM

457. It is often remarked in recent years, though perhaps without sufficient evidence, that nervous diseases are rapidly increasing. Cases of insanity, nervous prostration, insomnia, of mental and nervous weakness of various kinds, are at any rate so numerous as to give occasion for anxious inquiry as to the probable future of our race. It is, then, of the utmost importance that we should know how to order our lives so that our nervous systems may be preserved in health and vigor. All the bodily actions are dependent upon the reception of nervous stimulus at the right time, the right place, and in due amount, and when that fails, or is in any way deranged, the whole system suffers.

458. Nervousness is not to be understood as a sign of a particularly refined and delicate nervous constitution. It is due to a lack of control by the higher nerve centers and is always an indication of weakness or disease; always to be fought against by all reasonable means, and never to be accepted as a necessary feature of a sensitive organization.

459. Nutrition of the Nervous System. — Skillful and experienced physicians tell us that true nervous diseases, that is, disorders attended by actual degeneration or structural changes in nervous matter, are comparatively rare, and when they do occur are due to lack of nutrition rather

than to excessive demands upon the nervous organism. No part of the system is so carefully protected from injury, so hedged about and guarded from evil influences of every sort, as are the precious nerve centers. The nervous mechanism is the last to waste when the body dies from starvation, and under such conditions it is probably supported at the expense of other tissues as being more important than they.

Recalling what we have learned from previous study we shall see clearly the importance and the source of nourishment for the nerve cells. It is by the blood alone that they are fed. Every thrill of nervous influence destroys tissue, and unless an abundance of pure arterial blood is at hand for rebuilding the cells, weakness and decay will follow. Diseases which lead to blood poisoning — as pneumonia and typhoid fever — are accompanied with delirium, weakening of the mental faculties, or other nervous symptoms.

460. In order that pure blood may be furnished, the regular and perfect action of the digestive organs is indispensable. Digestion is a slow process; it cannot be hastened. If we eat our food so rapidly that it is not subjected to the action of the saliva, and is not properly divided by the teeth, the gastric juice will not be able to effect the necessary changes in the stomach, especially if we hasten to call the blood away for other work too soon, and the food will pass on into the intestines only half ready for the work of the other juices. Even in a healthy man the normal processes in the alimentary canal develop an amount of poison sufficient to kill him if it is not neutralized by the products of the liver, pancreas, and other organs, which nature provides for that purpose. So, if those secretions are interfered with, — as they are by the

use of alcohol, for instance, — or fail of their due action upon the food because the preceding processes are incomplete, the nutriment poured into the blood stream may carry disease instead of health and vigor to brain and nerve. It is just such inconsiderate habits in respect to eating which, as physicians well know, have led to many a serious case of "nervous prostration" among business men or students.

461. But the blood cannot be kept pure without a constant supply of pure air in the lungs. If that is lacking, there is at once defective nutrition of the nerve cells. Undoubtedly the nervousness so common among women is due, more than to any other one cause, to an insufficient supply of pure air for the lungs. Tight clothing which restricts the capacity of the chest, lack of outdoor exercise, and the breathing of vitiated and usually (in winter) too warm air are all direct causes of nerve weakness.

462. One more condition is necessary in order that the blood may be pure, and that is a healthy activity of the excretory mechanisms. If the worn-out material from the wasting tissues is not removed, it will remain to clog and poison the vital current. In a word, the condition of the brain and spinal cord, and the vigor and readiness of nervous reaction, depend wholly upon the distribution and quality of the blood, and those depend upon food, digestion, respiration, and excretion. It is true that a man does not die at once or become diseased because he has eaten improper food or breathed foul air. The physical organism has marvelous powers for contending against unfavorable conditions, a wonderful way of throwing off poison and rebounding from depression, so long as the natural vigor of tissues is not impaired by persistent abuse. But for each individual there is a point beyond

which recuperation becomes doubtful, wholly impossible, or only partial.

463. Fatigue of Nerve Cells. — A certain amount of activity in cells of all sorts is promotive of health. It causes a more rapid flow of the blood and greater storage of fresh matter to be afterward used in the liberation of energy. But too prolonged exercise or stimulation leads to exhaustion of the cells, and for every one there is a limit to the power of restoration after exercise. In the last stages of extreme fatigue it is the nerve cells and not the muscles which succumb to exhaustion. Microscopic examination of animals shows that the cells of the nerve centers gradually become shrunken and irregular in outline under stimulation, while the nuclei within the cells and in the inclosing wall are also seen to diminish. After refreshing sleep the cells are at their full size, the blood current passes at the normal rate through the nerve centers, and they readily respond to stimulus. At the close of the day a marked change has occurred in the cells of those centers. The rate of blood circulation has declined, and the stream is loaded with the accumulated products of the day's activities, while the diminished size of the nerve cells and their nuclei proclaims a state of fatigue.

464. Sleep. — It is by means of sleep that the nerve cells regain their form and their readiness to react on receiving stimulus. During sleep the nervous activities are greatly diminished. Afferent impulses do not set in motion the complex cerebral processes of waking hours. Consciousness is not excited, and memory fails to register the reception of impulses. Reflex movements may indeed result, but in the deepest sleep even such action is mainly lacking. Respiration and the circulation of the blood continue, but become slower, and a large amount of blood is

withdrawn from the brain. Much of the internal muscular and secretory mechanism becomes comparatively inactive. The whole body is affected by the changes brought about by sleep. We may describe the effects of sleep, though we are not able to tell what sleep is, or what are its causes.

That sleep is essential to the life of all those animals having a well-developed nervous system we know. Continued loss of sleep in man results in insanity and death much sooner than death follows starvation. Regular periods of sleep are needful, and nature provides for rest to the brain by gradually reducing the amount of blood circulating there when the accustomed hour for repose draws near. Then, as we say, we become "sleepy."

465. Necessary Amount of Sleep.— Sleep, to be recuperative, should continue uninterrupted for several hours. It has been shown by experiments upon certain animals that usually four hours or more are needed to reconstruct the shrunken cells. Short "naps," even though the aggregate be sufficient, do not restore and refresh the system as does continuous sleep. If the nerve cells are forced to work again before being fully restored, they do so under great disadvantages. Growing children require more sleep than adults, and a healthy, active child is not likely to take more than is good for him. For adults who work vigorously with muscles or brain, the old rule of eight hours is a safe one, though many are satisfied with less. Much depends upon habit and individual peculiarities. The old usually need less sleep than others. The processes of growth are long since completed, the activities of life are less, vital processes go on more slowly, and complete repair of the various tissues no longer takes place.

466 **How to induce Sleep.** — Insomnia has become so common of late that special attention should be paid to ways of promoting sleep. A great variety of drugs are used for the purpose, but some of them are extremely dangerous, and none of them should ever be taken except by the advice of a competent physician. Any activity of cells, any production of energy, — nervous energy as well as other forms, — gives rise to certain substances harmful to the body. By natural provision the presence of this waste matter in the blood causes a feeling of fatigue which inclines to a lessening of activity and gives opportunity for recuperation. To promote sleep, we cut off so far as possible the various sources of stimulus to the nerves. We recline at full length that the trunk muscles may be relieved from the effort to preserve the equilibrium. We remove all burdensome or uncomfortable clothing which might constantly excite the nerves of the skin. A warm bath just before retiring tends to allay external irritation and helps to withdraw the blood from the head. We darken the room and close the door against noise. For some hours before retiring our occupations should be free from excitement. One who is inclined to sleeplessness should do no evening brain work. A serene frame of mind conduces to repose. Although late and heavy meals are not to be recommended, it has been found that to eat moderately of easily digested food at bedtime will sometimes withdraw the blood from the brain and dispose to sound sleep. Active physical exercise during the day, sufficient to cause fatigue of the muscles, is usually followed by restful sleep. For brain workers a short period of active exercise before retiring — a quick walk or practice with dumb-bells or Indian clubs — may promote sleep. So may a hot foot-bath, or vigorous rubbing of the feet and legs, or other

massage. Other means for accomplishing the object of diverting the blood from the brain will occur to one who gives the subject thought.

A sleeping room should be well ventilated, dark, and quiet, the bed not too soft, nor the covering too abundant. A habit of going to sleep may be cultivated by lying down only at times when one wishes to sleep. By the laws of association the reclining posture will come to aid in inducing the cerebral condition desired.

467 **"Overwork."** — It is common to attribute most of the nervous disorders of our time to the overtaxing of the brain and nerves in business or study, or to excessive strain of the nervous system from anxiety or care. No doubt such cases occur, but other causes are far more prolific than these. The nervous system seems to be constructed to last as long as it receives nourishment enough and is allowed sleep enough. Among students there occur frequent cases of nervous derangement which could be traced, if all the facts were known, to causes other than overstudy. To keep a brain in health it must be used. Even severe mental application is promotive of health if practiced under healthful conditions. A student may break down because he uses his brain without taking sufficient sleep, exercise, and food to keep it in good condition, or fails properly to vary the kind of mental effort; but if he follows the various suggestions upon these points given in this book, he can hardly do so. There is no patent "brain food" which will supply the nerve cells with nutriment for their activities if it does not also build up all the other organs. The human life is one life. If one member suffers, all the members suffer. One cannot cultivate the brain into vigorous health while neglecting or abusing the stomach, the lungs, and other organs.

Proper habits of study should be acquired. One should learn to bring all his mental force to bear upon the work in hand — to *concentrate his thoughts*, as we say; that is, to hold his attention firmly upon the subject before him, and not dawdle over his book, letting his thoughts run from one topic to another according to chance suggestions, coming back only now and then to his work. Such practices weaken the brain and unfit it for effective labor. Severe, intense mental effort for a short time should be the rule, and then relaxation or complete change in the form of labor. But bad mental habits, abuse of the digestive organs, and the breathing of impure air are not the only causes of injury to brain and nerves. A life of overexcitement, which keeps the nerves continually a quiver in response to incessant stimulation, has shattered the nervous system of many a girl or young woman. Our American customs leave to the young too little space for the quiet, regular, uneventful living which promotes health of mind and body, strengthens for future usefulness, and stores energy for the severe and sudden emergencies of mature life. If a girl breaks down in health during her school years, her teachers are usually blamed as exacting too much brainwork, whereas the mischief is, in fact, far oftener due to unhygienic habits of life, to too rich or otherwise unsuitable food, to lack of air and exercise, and, especially, to too much social indulgence, along with late hours which interfere with regular and abundant sleep and use up the nervous force which should be given to study or stored for the future.

468. Habit as connected with Nervous Action. — Something was said upon this subject when reflex nervous action was considered, but its importance is so great that it should be further dwelt upon.

Habit is a law or property of the material world, and all our habits of life and action, mental as well as physical, are now understood to have their basis in the physical constitution of our bodies. The particles of matter which compose inorganic bodies act and react upon one another in a certain way, and ever after they act and react in that same way more easily, that is, with less resistance than in other ways, and by repetition of this action a habit is established. In organic bodies this property is still more marked. A pathway of discharge of nervous influence in the brain, once formed, is afterward the channel by which efferent nervous currents tend to pass outward. All our activities are due to this streaming outward of nervous currents excited by the constant streaming inward of other nervous currents, or by stimulation originating in the brain itself. A new channel once made for the outward flow becomes the path of least resistance for the next wave, which deepens the bed of the stream and determines more surely the course of following impulses. In course of time the nervous pathway becomes so deeply cut that, given a certain incoming impulse, the resulting nervous discharge can make its progress outward by that course alone which has been prepared for it by permitting previous impulses to pass that way. Then a habit has become "fixed," and we all know how difficult it is to change a fixed habit.

We have already seen how the possibility of acquiring habits relieves the brain of the necessity of attention to many of the movements of the muscles and vastly increases the number of things which one can do. Most of us establish in time an order of proceeding for the daily processes of dressing and undressing, for example, so that we go *through* them, day after day, in a certain routine without

giving any particular thought to them, and perhaps without knowing that we do make the necessary movements in the same succession, time after time. In such a case the first muscular contraction (as, for instance, the first voluntary motion after we have decided to retire to rest) is the setting in motion of a chain of events, each of which follows without thought from the sensation of the preceding muscular contraction. To change the order of the movements costs a definite effort, as when we decide for some reason to put on or off the left shoe first, when we have formed a habit of putting on or off the right one first.

469. Character. — It is the habits acquired which determine character. What a man has made himself by the time he is twenty-five or thirty years of age, through the pathways formed in the plastic substance of his brain, such he is almost sure to remain to the end of life. In many cases habits are by that time so strong that they *cannot* be changed. The brain seems to have become hardened, "set," so that new channels for nervous impulses can no longer be made. Even earlier in life many habits of daily practice have usually become unchangeably formed. The methods of speech, especially the idioms of ordinary conversation, for one's whole life, are those acquired in childhood. A man may become learned, polished, and scholarly in prepared or written productions while still retaining in daily familiar speech rude and uncultivated expressions learned in early years. It would be too much to say that even fixed habits cannot be changed, but to accomplish a change requires an amount of determination and persistence not common among men.

470. To build into the material substance of the nervous system a tendency to do right and wise acts in the

best way, to think pure and unselfish thoughts, to cherish the loftiest and noblest aspirations, is the most important business of youth. Manhood prepared by such training is ready for grand achievements. The spinal cord and the lower brain centers have been drilled to prompt and accurate reflex action, and much of the mechanical labor of life is left to their unconscious ordering. Not only are the ordinary movements of the body in walking, riding and the various athletic sports thus directed, but facility and correctness of speech, both oral and written, have become no longer matter for cerebral care. Rapid writing, attended by accuracy in respect to the accepted forms and rules of composition, has been acquired by thorough training, and the brain is left free to concentrate all its powers upon the higher activities of thought and imagination. That the products of those activities shall be worthy is determined by the abundant store of memories of worthy and beautiful objects, acts, purposes, and thoughts. Noble deeds will be inevitable because of the constantly repeated, voluntary turning of nervous impulses into channels for such results. Acts demanded by great and sudden emergencies, when deliberation and reason are impossible, will be unselfish, wise, and every way worthy because previous voluntary action has habituated all the nerve centers so to respond to stimuli received when judgment and reason have had time to consider.

471. Heredity. — Did each individual come into the world with all his powers in their normal condition, and grow up in the most favorable surroundings, such symmetrical and perfect manhood might be the expected and ordinary result. Unhappily that is not the case. Many eminent men of science believe that the impressions made upon the soft substance of a man's brain in early life are

so deep and lasting that they not only persist throughout the individual life, but also affect the brains and nerves of his children, and his children's children, so that they may have from their birth tendencies to act as their parents or their grandparents have been accustomed to act. They inherit a certain kind of *nervous temperament*, we say, and their nerve cells have a natural readiness to respond in certain ways to the influences which come to them. This may be a powerful aid to the development of upright and noble character, and it may be an almost irresistible force urging in the opposite direction. It has been observed in many cases that the children of criminals become criminal for generation after generation. The inherited *bent* of their minds appears to be evil, and as a rule their surroundings and associations are also evil. The power of a bad inheritance may, however, be neutralized by a good environment.

472. Influence of Alcohol on the Nervous System. — While the excessive use of alcoholic drinks works injury to every part of the body, it is largely through the direct effect of alcohol upon nervous tissue that the various evils are accomplished.

We will consider the physiological influence of alcohol on the nervous system under two heads: (1) *acute diseases caused by alcohol;* (2) *chronic diseased conditions.* Afterward the *moral* effects will receive attention.

473. Dipsomania (an acute disease) is the name given to the morbid craving for alcohol which renders a person utterly irresponsible for his acts while engaged in the mad pursuit of that which he believes will satisfy his consuming thirst. It is a distinctly diseased condition of the nervous system, and may result from what is only a slightly excessive use of alcoholic liquors by the sufferer himself, or it

may be due to a diseased state of nervous tissue inherited from an ancestor accustomed to such use, though he may never have indulged to the extent of intoxication. This form of alcoholism is now considered and treated as a disease by medical rather than moral methods.

474. Another acute form of alcoholism is called *delirium tremens*, and this is so terrible to witness, so frightful to suffer, that men speak the very name with bated breath. It occurs in persons whose nervous systems have been for a considerable time under the poisonous influences of excessive amounts of alcohol. At the height of the attack the patient becomes a raving maniac, subject to the most torturing illusions and sometimes, with the unnatural strength of madness, overpowering and escaping from several attendants. Repeated recurrence of the disease is almost certain to be fatal, though the first attack is rarely so. Permanent insanity may precede death.

475. **Chronic Diseased Conditions** arise from the gradual poisoning of the system by the continued use of beverages containing alcohol. Even though we admit that alcohol in a definite small amount is, in some cases at least, fully oxidized in the body, like other carbohydrates, and so supplies energy as food, we must never forget that different constitutions may be differently affected, and conditions as to climate, temperament, and habits of life may cause variations in its influence upon health and character. We can never know perfectly the nature of all the innumerable strains of hereditary tendency which unite to make an individual what he is. Some one of these may have impressed upon the nerve cells an instability, a weakness, a peculiar susceptibility to the influence of alcohol, so that the first taste may arouse the insatiable craving which leads to dipsomania. In another case, the inherited weak-

ness may render the child of an inebriate an epileptic, an imbecile, or a consumptive. We can never foresee just how the transmitted nervous weakness will manifest itself, but as a rule the descendants of those whose systems are poisoned by alcohol are enfeebled in body or mind or both.

476. But suppose a man to have derived from his ancestors a sound constitution and to have become addicted to the moderate use of alcohol; the insidious nature of the dangerous substance may gradually lead him to consume, insensibly perhaps, only a little more than the cells can oxidize. Without realizing it, he may slowly poison his system. The primary effect is upon the brain ; there is congestion and overexcitement of the nerve cells there—conditions which gradually extend to the nerve cells of the spinal cord ; inflammation sets in, and there follows fibrous degeneration of the tissues, substituting an inferior form for the specialized tissues which do the work of the organs in various parts of the body. Paralysis may result, or epilepsy, or dyspepsia from lack of the due amount of nervous influence upon the digestive organs, or any one of a thousand forms of disorder, some of which have been mentioned in preceding chapters. Though a man may never drink to intoxication, and never realize that he is using alcohol to excess, he may nevertheless become seriously diseased in consequence of his moderate indulgence, or what he believes to be such, while wondering why he is not well and strong. Still less does he consider the legacy of evil which he may be laying up for his children.

Life insurance companies have gathered an immense body of statistics respecting human life, with sole reference to their bearing upon the business of insurance, and

it is well known that life insurance companies regard policies upon the lives of drinking men — even "moderate drinkers" — as involving "extra risk." Their figures have convinced them that the man who uses no alcoholic beverages is likely to live longer than one who does.

477. Many believe that *climate* has much to do with the influence of alcohol on the nervous system. Our American climate is peculiarly stimulating to the nerves, and our systems are, in consequence, less able to bear the additional stimulation of exciting beverages, while the narcotic effects take place more readily than in other climates, and self-control is more easily overthrown. This is another reason, to us, for shunning the acquisition of the alcohol habit.

The influence of *race* has also to do with the prevailing use of strong drink and its evil effects. The Teutonic peoples are recognized as especially susceptible to the taste for intoxicants, perhaps because of their eager craving for excitement, for action, for enterprise; and because of that very craving they can indulge with less safety the appetite for stimulants.

478. The Moral Effects of Alcoholic Poisoning concern the individual himself, his family and friends, and the whole community of which he is a member.

The struggle of life grows more intense the world over; competition in all lines of effort is keener; success is more difficult. Every one has need of all his powers of mind and body at their highest possible level of efficiency. A man engaged in business needs every day and hour the use of the very best and most careful judgment, lest a false step — the buying of goods at the wrong time, the selling at the wrong price, a mistake as to quality or style, a *wrong* estimate of the tendency of the market — may

give his competitors an advantage and lead to his own ruin. In the professions it is no less true that no man should dare run the risk of befogging his judgment. A physician known to be a tippler will lose the best practice; the lawyer whose legal advice is sometimes cloudy, because of a trifle too much alcohol in his morning dram, will not command the confidence of those wishing counsel.

A man seeking employment is likely to be met at every turn by questions as to his habits respecting beverages containing alcohol and his use of tobacco. Several of the great railroad corporations employ only total abstainers in any capacity. Purely from pecuniary considerations they cannot afford to run the risk of accident upon their roads, — involving destruction of the property of the road, with also many thousands of dollars to pay for life and limb destroyed, — because perhaps a brakeman, having taken a "drop too much," was a little uncertain in his vision and did not grasp as quickly as usual the meaning of the signals; or because a telegraph operator had fuddled his brain with beer and had forgotten to send the dispatch which would have prevented a frightful wreck. So in respect to positions in the great commercial houses where trustworthiness, alertness, stability of character, are required; — it is those who drink neither brandy nor beer who stand the best chance, other things being equal, of securing desirable positions. In practically every walk of life a man is handicapped in the race if he is believed to be a drinking man.

All these facts clearly indicate the opinion of the world in general that, considered merely as a piece of mechanism for accomplishing various sorts of work, a man who takes no alcohol into his machine is worth more than one who does; so that a man who drinks thereby deliber-

ately lowers his own money value to the world and to himself.

479. But there are higher considerations than these. Alcohol in small quantities stimulates the cells to vigorous action for a time; then reaction and weakness may follow. In larger quantities alcohol produces, instead of a stimulating effect, a *narcotic* poisoning which paralyzes the nerves. This is first apparent in the higher cerebral centers, and if the poison is sufficient in amount, the paralysis extends till the whole voluntary portion of the nervous system is involved, leaving only the centers controlling the vital functions unaffected. The first glass of liquor may simply render a man unusually lively, talkative, perhaps brilliant, eloquent, entertaining, confidential, speaking freely of private affairs, revealing secrets. This stage will pass away before long, and if another glass is taken, and another, a progressive paralyzing of the mental faculties is seen. The ready flow of language disappears, utterance becomes thick, and ideas confused, stupor comes on, and the man falls to the floor "dead drunk," though circulation and respiration still go on. If he has taken alcohol *enough*, these too will cease, from the paralysis of the vital centers, and the victim will die. Occasionally a man runs through this course in a single debauch, but such cases are rare. Usually years of progressive deterioration precede the great catastrophe. The man's friends look on in helpless anguish. Noble manhood gradually sinks to the level of the beast, and below even that. He who was designed to be a mighty power for good to himself and to the world, becomes a curse to himself, a disgrace and a terror to his family and a burden to the community, *which* must employ police to watch him, build a hospital

or a prison to receive him, and must finally bury him at public expense and care for his unfortunate family. How is it that a being endowed with reason can deliberately put an enemy into his mouth to steal away his brains, and ruin body and soul?

Because one man whom we chance to know drinks daily a small quantity of wine or beer, and does not acquire that craving for more which leads to drunkenness, nor apparently injure himself in any way thereby, it is never safe to conclude that another man can do likewise. Nothing is more uncertain. At the same time it is a fact of common observation which no one will deny, that multitudes make shipwreck of manhood every year through the excessive use of alcohol; yet no one of them expected to be more than a "moderate drinker," not one but would have scorned the suggestion that he might in time become the vile drunkard of the gutter.

480. There is one infallible way of escaping these ills, and there is but one. That is to abstain wholly from alcoholic beverages. It is also a harmless way; it can do injury to no one. While it insures a man against the frightful evils of drunkenness, this course also makes it possible that by the force of his example he may help many a weak, tempted fellow-man to escape the seductions of the wine cup.

It may be an admirable thing for a man to be able to exercise the judgment, the self-restraint which permits him to indulge his appetite for alcohol to exactly that extent only which he believes to be harmless or helpful to himself, never yielding to a temptation to exceed the self-imposed limit. Is it not yet more admirable for a man to recognize the weakness of human nature, and the possibility — shown every year by thousands of sorrowful

instances — that even the manhood which seems strongest may be overcome, and so refuse to take the fearful risk of placing himself within the power of so insidious a foe? Does not the truest courage lead a man to avoid venturing needlessly and recklessly into the presence of so terrible a danger? And should not a man of really noble character deliberately choose to make his influence helpful, rather than harmful, to those weaker than himself?

481. Other Narcotics in Common Use. — Narcotics are very widely used by the human family for the relief which they give from pain or fatigue, or for the direct pleasurable sensations which they impart. All are deadly poisons when taken in sufficient quantities. Those most common (after alcohol) are *tobacco* and *opium.*

It has already been shown that tobacco may affect unfavorably many parts of the system, and is especially injurious to the young. It stimulates in small quantities and narcotizes in larger ones, working its effects directly upon the nervous system. *Nicotine* is a powerful poison found in tobacco. It affects the nerve cells, injures the brain, and leads especially to weakness of the heart by interfering with its supply of nervous force. Many cases of cancer of mouth and throat are believed to have resulted from tobacco smoking.

Opium, for its benumbing influence upon the nerves, is used by large numbers of persons, especially in Oriental lands. Its continued use deranges all the digestive processes, disorders the brain, and weakens and degrades the character. Like alcohol, it produces an intolerable craving for itself, and the strongest minds are not proof against the deadly appetite.

482. Self-control versus Appetite. — Man is a bundle of appetites. Every organ, every cell even, craves its appro-

priate stimulus. Animals under natural conditions gratify the appetites as they arise only to that extent which is healthful for the whole body. Man alone, whose highly developed brain is overlord to the rest of his system, permits an unwholesome indulgence of appetite to interfere with this general well-being. Alcohol, opium, and their like are far from being the only substances whose excessive use injures the organism and degrades character. Children are often allowed to indulge a natural fondness for sweets to an extent which is ruinous to digestion; for sugar, which is a useful and necessary food in suitable quantities, becomes in larger ones a poison to the system. Boys pampered with dainties from infancy logically infer that a fancy for cigars or beer may be similarly gratified. Appetite for even the most wholesome food may be in excess of bodily needs, and the practice of gluttony is certain to derange nutrition.

A child should be early taught that because he "likes" a certain article of food he should not therefore continue to eat it after natural hunger is satisfied, or at times when he does not need food; while to persist in eating or drinking that which experience, or the advice of those competent to judge, has taught him to be harmful, should be regarded as unworthy a rational being.

These are but illustrations of the manifold forms of intemperance which work untold harm to the physical and moral natures. There seems no possibility of improvement to our race except as the young are led to recognize the manliness and dignity of controlling one's appetites.

483. And it is not in respect to the delights of the palate only that a foolish self-indulgence prevails. The love of selfish pleasure in any form may be developed

it encroaches upon the general well-being. Man's ason was designed to dominate all the appetites, to fy them only so far as will conduce to the best use he higher capacities. If the mind does not rule and train the appetites by the dictates of reason, then the y and not the mind is on the throne, and man sinks the level of the beasts that perish. Temperance in all ngs, a wise moderation according to reason and expeience, subordination of th tites and passions of the ysical being to the nobler irements of the spiritual ature, and to the still fine ment of unselfish consecration of all one's powers service of humanity—these are the principles wh minate the highest type of manhood.

PART V

THE PRESERVATION OF HEALTH

CHAPTER XXIV

HEALTH AND DISEASE

484. Health, in man, is that condition of the organism in which all the various parts composing it perform their functions perfectly, so that the largest amount of the best work of which the being is capable is performed easily and without discomfort. Health is attended with a feeling of buoyancy, vigor, and happiness. Disease is the result of disordered action in some one or more parts of the organism, usually long-continued and affecting more and more the various vital processes.

Many of the ways in which persons are accustomed to injure the health by inattention to hygienic rules, or by violations of them, have been alluded to in preceding chapters. Incorrect habits of life are the direct cause of many diseases, and indirectly cause many more by weakening the organs, and preparing the system to yield readily when exposed to the influences of specific disease.

485. Bacteria. — It is now known that several forms of disease arise from the growth and multiplication, within the body, of certain microscopic forms of life called bacteria, or bacilli, or microbes, or germs. These are living

cells belonging to the lowest orders of plants. They possess the power of rapid increase by repeated division of the cells, so that many millions may be produced in a short time from a single one. They are propagated also by means of very minute spores, which may float in the air, mix with the dust of a street or a room, or cling to walls, clothing, or furniture. Only moisture, warmth, and albumin for food are needed for their growth. Probably most (perhaps all) of these tiny organisms have some useful part to play in the infinitely varied operations of nature; but a few varieties are known to be enemies to human life and health. Certain sorts of bacteria are always concerned in the putrefaction of organic matter, that is, as they multiply they break up the complex compounds in vegetable and animal substances, and reduce them to simpler chemical forms which may again be used as food for plants. Thus dead animal and vegetable matter is being constantly oxidized by the bacteria found everywhere in the soil, and rendered fit again to support life. In this they of course minister to man's welfare, although the process of decay is attended by the production of deadly poisons, which may enter the body and cause disease.

486. Bacteria within the Body. — The dry speck of dust which is the spore, or germ, of a disease may, while it remains dry, exist for an uncertain number of years as an inert, harmless bit of matter. It may be subjected for weeks to cold many degrees below zero, and even for a short time to heat above that of boiling water, without destruction of its vitality. It may then fall upon a moist bit of albumin in the air passages of a man, or in the alimentary canal, or in blood or lymph through a broken surface, grow with wonderful rapidity, and swiftly poison

the whole body. The dangerous germ may, indeed, be caught by the moist surface of the mucous membrane and removed before it has done harm; for it is one of the functions of the moist lining of the winding nasal passages to strain out the irritating and disease-bearing particles from the air, and the ciliated epithelium of the lower air passages also affords protection in the same way. Expired air is practically free from germs and other dust. What we call "taking cold" is now believed to be due to the poisonous action of bacteria fastening upon the mucous membrane where the cells have been injured by cold or in some other manner. Finding food at the injured spot, the bacteria multiply and cause inflammation of the air passages and general discomfort, sometimes resulting in disease.

487. It has been found that a large number of bacteria of several varieties are always present in the human mouth. The saliva has the power of destroying a limited number of the harmful kinds, but others remain to multiply. Certain sorts cause decay of the teeth (where the enamel is defective). Others may make their way into the lungs or the stomach. As they grow they manufacture from the albumin which they decompose, certain poisons, called *toxins*. These may enter the circulation and carry the deadly influence to all parts of the system. If the stomach is healthy and the gastric juice normal, many dangerous germs will be destroyed in the stomach. It is even shown by experiment that those of cholera and typhoid fever are quickly killed by the gastric juice. Other germs have greater resisting power and are able to multiply in the stomach, causing dyspeptic symptoms or specific disease. Some forms of bacteria feed upon and destroy other forms. Many sorts escape the destructive action of other germs

and of the digestive juices, and reach the intestines to develop there. Still other kinds are always normally present there. Immense numbers are always found in the contents of the large intestine. The bile, which is known to have the power of preventing putrefaction, appears to be able to modify the action of the microbes and to keep that action within certain limits which may render it helpful to digestion.

Taken in through a wound in the epithelium, the noxious germs cause inflammation and swelling, and their toxins may circulate through the body. Or by the wonderful power of the white corpuscles of the blood, which feed upon the bacteria in the blood, the evil may be neutralized. The plasma of blood and lymph seems also to possess the property of destroying certain toxins, or of protecting the system from their action.

488. **Antitoxins.** — In recent years some marvelous discoveries have been made respecting nature's way of counteracting in the body the effects of certain germs of disease.

It has been shown that in the progress of certain infectious or contagious diseases there is developed in the serum of the blood or in the tissues a substance which is a poison to the bacteria causing the disease, or a substance which neutralizes the toxins produced by them. In course of time — it may be days or weeks — enough of this substance, called *antitoxin*, is manufactured to neutralize the toxin or to destroy the germs of the particular disease, and the patient recovers. In certain cases, as in measles, smallpox, whooping cough, etc., this protecting substance seems either to remain in the blood or to be continually produced for the rest of life, giving permanent security from the disease. In others, such as diph-

theria and pneumonia, the security given by the antitoxin is only temporary.

Certain animals are known to be subject to some of the same diseases which attack human beings, or to be susceptible to them when the particular poisons are introduced into their systems. Other animals cannot be made to "take" certain infectious diseases, even when the specific germs and toxins are injected into their circulations. They are said to be "naturally *immune*" to those diseases, that is, an antitoxin is supplied by nature in their blood serum for the germs or toxins of those diseases. Other animals are rendered immune to certain diseases by having experienced them.

Advantage has been taken of this knowledge respecting animals for the benefit of man. In several cases the antitoxic substances in the blood of animals immune to certain diseases have been separated out and injected in minute quantities into the veins of human subjects suffering from the particular infection. The proportion of recoveries when the antitoxins are used under proper safeguards is increasingly and encouragingly large.

489. Vaccination for smallpox was the first great discovery in this direction. By means of it smallpox, which was once the great scourge of the human race, — as common as measles or whooping cough is now, — has become comparatively rare. The use of the diphtheria antitoxin, which is derived from the blood serum of a horse which has been innoculated with the diphtheria germ, is fast becoming general, and we may hope to see diphtheria — that terror of childhood — disappear with the advance of beneficent science.

The greatest destroyer of human life which now remains is consumption, — tuberculosis in its varied forms, — and

there is reason to believe that it also is destined to be overcome by the progress of scientific discovery, together with a wider diffusion of sanitary knowledge. An antitoxin for consumption, called *tuberculin*, has been found by cultivating the germ obtained from the mucus raised by consumptive patients, in a substance found to favor its development. This new remedy is yet so recent, and the number of experiments made so few, that nothing positive can be stated as to its value. But there is good reason to hope that a trustworthy cure for tuberculosis will in time be in common use.

490. **Antiseptic Surgery** is another result of the study of the new science of bacteriology. (*Antiseptic* is derived from two Greek words meaning "opposed to putrefaction.") The great danger connected with wounds and injuries has been found to be due to the opportunity which they give for harmful germs and spores to enter the system. This is now guarded against by the practice called *sterilizing*, applied to all instruments and appliances used by the surgeon, and so far as possible to the operating room itself. The object is the destruction of all germs. The instruments used are previously boiled for a sufficient time to kill all known forms of life. Towels, operating gowns, all cloths, dressings, and other things used are sterilized by heat or antiseptic chemicals, and every possible precaution is taken to prevent the access of any bacteria to the exposed surfaces. As a consequence, the severest wounds often heal in a few days, and the most astonishing operations are performed with comparatively slight risk.

491. **How to avert Danger from Poisonous Germs.** — To a person in perfect health it is probable that bacteria of all sorts are harmless. The healthy stomach seems able to

digest typhoid-fever germs as well as its natural food. To avoid disease, then, we have but to keep the whole system at a high level of health and vigor. But few are so fortunate as to possess and maintain perfect health, and it is necessary to guard against the entrance of disease germs into the body.

Careful attention to cleanliness of person and surroundings is of prime importance. The free use of soap and water, and the daily cleansing of mouth and teeth, are safeguards. Many thousands of bacteria have been counted in the dirt lodged under a single finger nail, and they swarm in soiled clothing. Some of them may be germs of disease.

All excretions from diseased persons should be treated as dangerous to health, and at once disinfected by fire or by other methods under competent direction. In cases of pulmonary consumption or other diseases of lungs or throat, all discharges from the respiratory passages should be received upon pieces of soft paper or cloth and immediately burned. The unseemly practice of spitting in public or in private places should be abolished. It has undoubtedly been in past ages an active cause of the spread of diseases of throat and lungs. The dried *sputum* is carried hither and thither by the air, to be breathed in by unconscious victims.

492. In respect to cleanliness of dwellings and their surroundings we are becoming, year by year, more intelligent. We know that oxygen and direct sunlight destroy many harmful germs, and we are learning to banish from our homes dark and heavy draperies which exclude sun and air and harbor dust, as well as carpets nailed to the floor and hence not easily and often cleaned. We burn the sweepings from our rooms instead of scattering them

upon the wind, and do not allow our washtubs to be emptied upon the ground beside our door. We seek as much light as possible for our cellars, and take care that nothing is left there to decay. We look well to the source of the water used in our homes, lest it should bring to us illness and death, and we have a wholesome fear of "sewer gas," which leads us to keep all pipes and drains well cleansed and in good repair.

All this is but putting in practice the rules of cleanliness which have been known for ages to be necessary to health. But we are now acquainted with many invisible and deadly forms of filth unknown to our ancestors.

493. Dangers to Health in Rural Districts. — It would seem that life in a country village or upon a farm, where every house may be continually surrounded by pure air and exposed to abundant sunshine, should be free from the unfavorable influences which assail dwellers in towns and cities. As a matter of fact, however, the same ignorance and carelessness which are found in the city appear also in the country. Sanitary precautions are needed upon the farm no less than elsewhere. How often do we know of farmers' families suffering from malarial or typhoid fevers, and how many children have died upon farms from diphtheria! Because of their peculiar advantages country dwellers are too often peculiarly careless. Wells for family use are frequently placed where the leakage from barnyard or cesspool will inevitably pollute the water when the soil has become saturated. Even if the well is at some distance from all apparent sources of contamination, and upon higher ground, it is impossible to tell what may be the underground conditions, what may be the slope of the strata, and whether or not there is poisonous leakage. In some cases the well is, for conven-

ience, very near the house, while upon the ground around it is poured all the liquid waste of the household, no provision being made for drainage. The soil then becomes saturated with filth, which every shower washes into the well. Sometimes a country dwelling is so closely surrounded by trees as to shut out the sun and air and cause unhealthful dampness. Convenient opportunities for frequent bathing are often lacking, and in winter there is apt to be too little attention to ventilation. With only a moderate amount of intelligence and care, life in the country might be made far more healthful.

CHAPTER XXV

COMMON ACCIDENTS AND INJURIES

494. Surface Wounds. — When the surface in any part of the body is cut or torn, bacteria at once fasten upon the moist parts and begin their harmful work. But for their presence most injuries would quickly heal. Nature provides that the white cells in the blood shall multiply about the wound to form a new tissue. They also have the power of absorbing and destroying dead cells and foreign matter in the cut. New blood vessels grow in the injured part and carry the material needed for building the new tissue, while the cells of the cuticle also grow from all sides to cover the exposed surface. But if poisonous bacteria enter the wound, as they are almost sure to do, they must be destroyed by the white blood cells before healing can take place, and the process is attended with inflammation, swelling, and pain, besides being much prolonged. The edges of the wound should be pressed together and kept in place by bandages or plasters. Unless foreign matter, such as sand, glass, or splinters, is believed to be in the cut, the blood should not be washed away, but left to clot and assist in the restoration of the tissues. If nature is assisted by the use of dressings and coverings which prevent the entrance of bacteria, the cure will be much hastened.

495. Injuries to Blood Vessels. — If the capillaries merely are hurt the blood only oozes slowly ; a clot will soon be formed and the healing process begun. If a vein is opened, the blood flows in a steady stream and is of a dark purple color. But when an artery is divided, the blood from it is bright scarlet and comes in spurts, corresponding to the heart beats. Bleeding from an artery is the most dangerous and the most difficult to check. That from capillaries and small veins will ordinarily check itself by the formation of clots, but the flow from an artery may be so fast as to prevent clotting. A doctor is usually needed, but no time must be lost in waiting for him. Strong pressure must be at once applied upon the artery, either in the cut or *between the cut and the heart.* If the injury is to a limb, a handkerchief or other bandage may be tied (in a knot that will not slip) around it above the hurt, the hard knot placed over the artery, and a stick inserted under the bandage (Fig. 139). By twisting the stick the knot may be pressed upon the artery hard enough to stop the bleeding. A firm hand may be able to effect the same object with the thumb and finger, changing from place to place till the right spot is found. Or a strong rubber band or tube may be stretched, wound round and round the whole limb, and tied.

Fig. 139. — Manner of compressing an artery with a handkerchief and stick.

A knowledge of the course of the principal arteries is

desirable. That of the arm runs in the middle of the inside of the elbow (Fig. 140) and along the middle of the under side of the upper arm, just opposite the arm-

Fig. 140. — The left upper arm.

The dotted line indicates the course of the main artery (the brachial).

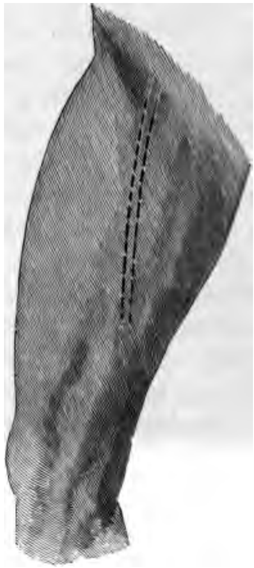

Fig. 141. — The right thigh.

The dotted line indicates the course of the main artery (the femoral).

pit. In the leg the main artery is in the middle of the hollow behind the knee and in the middle of the hollow between the thigh and the trunk (Fig. 141).

496. To stop bleeding from a vein, apply pressure *between the cut and the extremity*, that is, *on the side away from the heart.*

Bleeding from the nose may often be stopped by applying cold water, snow, or ice to the back of the neck, the

forehead, and upper part of the nose. Other remedies are to raise the arms high above the head, and to snuff up the nostril a solution of alum or other astringent.

497. When blood comes from the stomach or the lungs, it is usually a serious symptom, and calls for medical attendance. The patient should be kept quiet in bed, and small bits of ice should be swallowed frequently.

Broken Bones and Injuries to Joints. — See pp. 55, 56, in Chap. IV.

498. **Asphyxia, or Suffocation,** may occur from various causes, as strangulation, drowning, the breathing of certain gases, convulsions which close the throat, etc. The immediate cause is always a lack of oxygen in the lungs, and *fresh air* is always the remedy, though that alone is not always a sufficient remedy. Artificial respiration is sometimes necessary. (See § 499.) Sometimes the heart ceases to beat from an accumulation of venous blood in the right side, because the unpurified blood will not circulate through the lungs. In such a case the physician may draw a little blood from a vein, — after the air passages have been opened and fresh air supplied, — and so start the circulation.

The most common cause of asphyxia, except drowning, is probably the breathing of poisonous gas from a choked or defective coal stove, from burning charcoal, or from a gas burner. Fresh air, if supplied in time, will always restore, though the system may show symptoms of derangement for days or weeks afterward.

499. **Apparent Drowning.** — Efforts to restore persons apparently dead from drowning should be persevered in, even though no signs of life appear for several hours. Quickly remove all clothing from the upper part of the body. Turn the patient on his face, with a large, hard

roll of clothing across the pit of the stomach. Let attendant throw his own weight heavily two or tl times for a moment upon the patient's back, to forc the contents the stomach at the mo Gently cle the mouth v a handkerc wrapped rour finger. Then mediately set *artificial bre ing*. Turn body upon the back, with the head slightly raised the roll of clothing placed under the chest. Knee the head, grasp the arms above the elbows and ge raise them above the head, holding them there tw three seconds. Then bring them carefully down, press them firmly for the same length of time against the sides to expel the air. Repeat these movements rhythmically from twelve to fourteen times a minute. See that the tongue is drawn forward and not allowed to slip back to close the throat. E after signs of life appear — often only as a faint pink

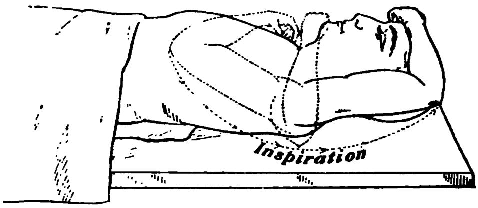

Fig. 142. — Diagram of artificial respiration, showing inspiration.

The arrows show that the arms are moved outward from the sides of the chest.

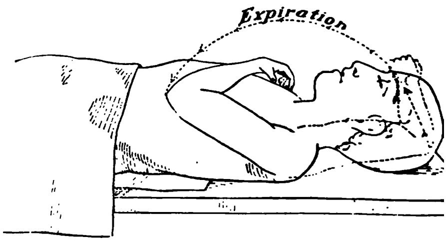

Fig. 143. — Diagram of artificial respirati showing expiration.

The arrows show that the arms are carried rectly forward until they are pressed hard ag the chest.

color in finger nails or lips — continue the artificial respiration till natural breathing is well established. Keep the patient cool, and in the open air if the weather is not too cold. Do not use the galvanic battery. Dry, warm clothing must be provided as soon as life appears; warm drinks should be given, and the patient will usually need to be kept in bed for some days.

500. Other methods of artificial respiration are in use. In one the patient is placed face down, with a roll under the chest, the head on one arm. One person then gently rolls the body upon the side for two or three seconds, while an assistant supports the head. Then the body is returned to the first position for two or three seconds, and the movements are regularly alternated for hours, or until natural breathing is set up.

Even the forcing of air into the patient's lungs from the mouth of another has proved successful, and one well-known method is to insert a tube into the trachea and force in air from a bellows.

501. Burns and Scalds should be treated with great care in a way to avoid chafing and to exclude the air. Cold water may be applied immediately to relieve the pain. Soft linen, wet in a very strong solution of common baking soda, or a thick covering of wet soda, is good. Carron oil, which is a mixture of equal parts of linseed or olive oil and lime water, is an excellent remedy. Vaseline is useful to exclude the air. Deep or extensive burns or scalds should have immediate medical care.

502. A burn by lye, ammonia, or other *alkali* should be treated at once with *acid* — dilute vinegar or lemon juice. A burn by *acid*, on the other hand, will be relieved by applications of dilute *alkali*, such as ammonia or a solution of soda.

503. When Clothing takes Fire the sufferer should lie d at once and roll over and over to smother the flame. St ing up allows the fire to reach the head and perhaps t breathed into the lungs, while running fans the flame makes it spread. A rug or any woolen garment at h should be thrown over the sufferer, care being take cover neck and shoulders first, and so to force the downward, away from the head and face.

504. Frost Bites. — Intense cold destroys the cells of surface, as does intense heat. Fingers, toes, nose, and are the parts first "bitten." They become colorless insensible, showing that the circulation in the frozen has ceased. Every sort of warmth must be avoided the circulation has been gradually restored. Rub chilled parts hard with snow or with ice water u sensibility and color return.

Parts which have been frozen generally remain parti larly sensitive to cold. Chilblains often result from v slight exposure and cause much discomfort. The p so affected should be bathed often, care being taken wipe them perfectly dry, and they should not be brou near a fire, as heat increases the irritation.

505. Sunstroke, or Thermic Fever, results from expos to extreme heat from the direct rays of the sun or ot source. Anything which lowers the vitality of the b — such as great fatigue, ill health, and the use of alcoh drinks — helps to render one susceptible to the effects high temperatures. When the air is stagnant and loa with moisture as well as very hot, as it may be in cl confined rooms or streets, there is greater danger of s stroke than when the atmosphere is dry and circul freely, though the thermometer may stand higher.

A person suffering from heat fever is prostrated s

denly, and usually becomes unconscious. His blood temperature may, in severe cases, rise to 112°, or even higher, and death is likely to follow soon unless prompt relief is given. The immediate cause of the alarming condition is the effect of heat upon the nerve centers at the base of the brain, which control respiration and the circulation. Death is due to the paralysis of those centers.

Treatment consists in lowering the temperature of the body as rapidly as possible, by the use of ice and very cold water. No time must be lost in applying these to the whole body, by means of wet sheets, by sprinkling with the coldest water at hand, or by rubbing with ice.

Special sensitiveness to heat often remains long after recovery from sunstroke.

506. Choking. — Small bodies often stick in the throat, and can neither be swallowed nor coughed up. Sometimes they can be reached with a finger or forced out by sharp strokes upon the back between the shoulders, or by tickling the inside of the throat to cause vomiting. If a hard substance is lodged in the trachea a surgeon must be called at once.

If hard objects are swallowed, they should usually be left to pass off with rejected portions of the food, without the use of physic. Bread, cheese and crackers may be eaten freely, that the foreign body may be surrounded by the stiff, pasty material, and pass easily through the alimentary canal.

507. Foreign Bodies in the Eye. — Dust, cinders, etc., get under the eyelids and cause much discomfort. As the conjunctiva, or lining membrane covering the inside of the lids and the front of the eyeball, is one continuous sheet of tissue, these particles cannot get behind the ball and can usually be seen and removed. Often the flow of

tears caused by the irritation of the troublesome substance washes it away, or it may be wiped off by a fold of soft linen. But it is sometimes lodged far under one of the lids — usually the upper one — where it is not so easily reached. In that case let a friend take the lashes of the lid in the fingers of one hand and turn the lid gently up over a knitting needle or slender pencil held in the other hand across the middle of the lid. Then if the ball is rolled downward, and from side to side, the source of irritation can be seen and removed. Care must be taken not to increase the inflammation by rubbing the eye. Applications of hot water will give relief in cases of slight inflammation.

508. Foreign Bodies in the Ear are sometimes difficult to remove. Syringe the passage gently with warm water; to drive out insects, drop warm salted water into the ear. If such efforts do not avail, no violence must be used, but a surgeon must be called in.

509. Foreign Bodies in the Nose. — Small buttons, cherry stones, peas, beans, etc., are often crowded by children so far up the nostrils that they cannot be reached. The child can sometimes remove such an object by "blowing" the nose hard, or it may be removed by slapping the child's back. Occasionally a surgeon is needed.

510. Sudden Illnesses. — *Fainting* is directly caused by a lack of blood in the brain. It should be treated by placing the patient on his back with head and chest slightly lower than the rest of the body. Plenty of fresh air should be given; cold water may be dashed over head and neck. Clothing should be loosened, and in severe cases artificial respiration may be needed. Strong ammonia or smelling salts applied to the nostrils is sometimes useful.

511. *Epilepsy, or Fits*, is an alarming nervous attack attended by unconsciousness and sometimes by foaming at the mouth. It is a chronic affection, and has been known from very early ages. Julius Cæsar and Napoleon Bonaparte are both said to have been epileptics. Little can be done during the paroxysm except to loosen the clothing and see that the sufferer does not harm himself. A pad of cloth crowded between the teeth will prevent biting of the tongue.

512. *Hysterical Fits* occur oftenest in young women, and usually follow emotional excitement. The patient laughs and cries, sometimes drops to the floor, and disorderly, almost convulsive movements may take place; but the tongue is never bitten, nor does the patient harm herself. Dashes of cold water may cut short the attack. Calm, firm, quiet remonstrance from a strong-minded friend without much appearance of sympathy will be helpful.

513. *Convulsions* in young children sometimes occur during teething, and at the outset of some serious diseases — as scarlet fever and diphtheria. They may also be a result of overeating or of deranged digestion. If the muscles are not quickly relaxed by placing the child in a warm bath, a physician should be called without delay.

514. **Poisons.** — A poison is any substance which is capable, when taken into the body, of producing effects injurious to health and life. Various substances in common use in the household — such as ammonia, lye, ratsbane, carbolic acid and other disinfectants — are poisons. Many medicines (in sufficient quantities) are poisons, and all medicines should be carefully labeled and used only at such times and in such quantities as are prescribed by a physician.

515. Poisons are usually divided into two classes: corrosive or irritant poisons, and narcotics.

Corrosive poisons cause great changes in the tissues. In this class are included all those which affect the skin, causing inflammation and sometimes destruction of the tissues; those which act upon the mucous membranes of the alimentary canal, giving rise to inflammation, nausea, vomiting, pain, and purging; and those which act upon the mucous lining of the respiratory organs. These last are usually gases. A poison to affect the system must be in liquid or gaseous form, but solid poisons may be quickly dissolved by the fluids of the mouth or the stomach, or the exudations from the broken surface of the skin, and the solution becomes dangerous. Some solid poisons, however, dissolve so slowly that they may pass through the alimentary canal and be expelled from the body without doing harm. Those poisons which enter the blood, and by causing alterations in it, or by circulating in the blood, injuriously affect various organs, belong to the class of irritants. The symptoms resulting differ as one organ or another is most affected.

516. Narcotics do not produce marked tissue changes, but affect chiefly the nervous system. The results vary greatly. Sometimes convulsions, cramps, delirium; sometimes depression, sleep, or stupor may be caused. Narcotics work their effects more slowly than do the irritants, and the particular symptoms which appear depend so much upon the special susceptibility of the individual that diagnosis is often very difficult. Some poisons which produce narcotic effects are also corrosive to the tissues, so that the classification into irritants and narcotics is not an absolute and scientific one.

517. Treatment. — In case of poisoning, the object of

treatment is to prevent absorption of the dangerous substance and local injury to the tissues. It is usually desirable to cause vomiting. This may often be done simply by thrusting a finger into the throat; or a tablespoonful of ground mustard, or of common salt, in a glass of warm water, or even lukewarm water alone may act as an emetic. Vomiting should be induced repeatedly, and then the antidote for the poison, if known, should be given; and, if the poison is an irritant, slimy fluids, such as white of egg, mucilage, flaxseed tea, or barley water, should be swallowed in order to protect the walls of the alimentary canal from its action. In certain cases, however, emetics should not be used.

518. Table of Common Poisons; Symptoms and Antidotes. —

POISONS	SYMPTOMS	TREATMENT
Acids Carbolic Hydrochloric Nitric Oxalic Sulphuric (the most serious)	Blistering and burning of the surface; intense inflammation of stomach. Carbolic acid causes nervous symptoms also — great weakness.	Weak alkalis, magnesia, common soda, chalk, soap, dilute ammonia, etc., afterward mucilaginous drinks, white of egg, milk, etc. For oxalic acid give lime; other alkalies are not antidotes for it. Treat corroded surfaces like burns. Give no emetic.
Alkalis Ammonia Caustic potash, or soda Lye Saltpeter	Symptoms similar to those caused by acid poisoning.	Weak acids — vinegar, or lemon juice; olive oil, melted butter, cream. Give no emetic. Soothing applications to surfaces.

POISONS	SYMPTOMS	TREATMENT
Arsenic Paris green Rat poison Mercury, as corrosive sublimate Lead, as sugar of lead, or white paint.	Vomiting, inflammation of stomach, cramps in abdomen, thirst; sometimes abdominal symptoms almost absent, and delirium, coma, convulsions, lead to speedy death.	Cause repeated vomiting (except in mercury poisoning). The antidote for arsenic is *oxide of iron;* for lead, Epsom salts. After the antidote for arsenic, give strong solution of common salt; after Epsom salts give oils, flour and water; for mercury, give white of egg, milk, or other albuminous material.
Phosphorus from matches, rat poisons, phosphorated oil.	Severe pain in stomach, eructation and vomiting: gases and solids having phosphorescent odor. Later, unconsciousness, collapse, convulsions.	Stomach must be emptied thoroughly. Give strong soapsuds or magnesia in water. Do not give oils.
Strychnine	Intense excitement of spinal cord and general nervous system, causing cramps, convulsions, lockjaw, etc.	Chloral, opium, and bromide of potash are antidotes; empty the stomach as quickly as possible, then give antidote.
Chloral	Deep sleep without previous excitement, passing into coma, death resulting from sudden heart failure.	Stomach must be quickly emptied and strong stimulants given—such as strychnine, atropine, etc.

POISONS	SYMPTOMS	TREATMENT
Opium Morphine Paregoric Laudanum Dover's powder Soothing sirups, etc.	First, state of mild, mental excitement; later, drowsiness, sleep, then complete unconsciousness, while pulse grows weak and irregular, skin cold and moist. Pupils of the eyes grow smaller and smaller, respiration becomes very slow, and patient dies from failure of breathing.	Stomach must be emptied and repeatedly washed out with water. Patient must be kept awake by constant movement, dashes of cold water, strong coffee, or even strychnine. The muscles of respiration may be stimulated by electricity; and cases where death has apparently occurred may be saved by forced artificial respiration.
Aconite	General numbness, weakness, and cold sweat; tingling in throat.	Cause free vomiting. Give stimulating drinks — coffee, etc.
Belladonna	Eyes bright, pupils dilated; mouth and throat dry. Sometimes convulsions.	Empty the stomach thoroughly. Give tannic acid or strong bark tea.
Other Vegetable Poisons Wild parsley Bitter sweet berries Mountain ash berries Indian tobacco Toadstools Hemlock Tobacco, etc.	Nausea, weakness, stupor, etc.	Empty the stomach and intestines; give stimulants.

POISONS	SYMPTOMS	TREATMENT
Putrefactive Poisons Foods which have begun to decay sometimes give rise to deadly poisons. These most often appear in meat, sausage, and cheese; while a particular poison called *tyrotoxicon* is developed in milk, ice cream, etc., which have stood long in vessels not kept perfectly clean, or in rooms where germs of decay exist—as from decaying wood.	Symptoms vary greatly. There is, usually, pain in the digestive organs; sometimes vomiting and purging, followed by weakness.	Give mild emeti mustard or p dered alum in wa water—then v gar and wat Castor oil may given to empty intestines.
Animal Poisons Snake bites	Local pain and swelling, followed by great weakness, dizziness, blood poisoning; sometimes death.	Apply tight ligat between the wou and the heart. O the wound and w with solution permanganate potassium; or t poison may drawn out by su ing with the mou or with a cupp glass. In seve cases the wou should be burn with hot iron caustic. Give stim lants to support t system.

POISON	SYMPTOM	TREATMENT
Insects' Stings Wasps Hornets Bees Mosquitoes, etc.	Swelling, pain; in severe cases followed by weakness.	Generally little treatment is needed. Bathe with carbolic acid, diluted with water, to relieve smarting. Some insect stings are acid, some alkaline. If the application of ammonia or wet soda does not relieve, try vinegar or lemon juice.

CHAPTER XXVI

PUBLIC HYGIENE, OR GENERAL SANITATION

519. Definition.—As personal hygiene is the art and t science of preserving the individual body in health, public hygiene is the art and science of promoting t health of the community. A healthy man is one wh(body is sound and vigorous in all its parts, so that all t functions of the system are performed perfectly, easi and without discomfort; no one of all the organs negle ing or failing to do the work assigned it, and so derangi or poisoning other organs.

A healthy village or city is one in which most of t inhabitants are healthy, and especially one in which co tagious and infectious diseases do not pass from one pe son to another.

We have learned that a man, in order to maintain l health, must have pure air, pure water, and wholesor food. But in crowded towns and cities even the wealt iest citizens are not able to procure these simple necessiti for themselves. The carelessness of some obscure aı ignorant person may poison the water supplied to ri and poor alike; germs of disease from the most squal part of a city may be borne by the air, by the gas of sewer pipe, or in any one of a thousand other ways carry death to a palace many miles away. A single filtl dwelling may poison a whole town. It is not enoug

that intelligent persons should themselves live according to sanitary laws ; it is necessary to their health that the ignorant and careless should also be obliged to do so. This cannot be brought about by individual influence or authority. Hence it has come to pass that in all civilized communities some degree of control is exercised by the officers of the government over the personal habits and ways of life of private persons. Many of the laws given by Moses to the Hebrews and preserved in the Scriptures relate to sanitary matters connected with daily life, and it is believed that obedience to those laws has had much to do with the fact that the Jews, throughout their history, have been remarkably free from great epidemics of disease. Neglect of sanitary precautions is, on the other hand, understood to be responsible for the frightful "plagues" which often swept over the earth in past ages, destroying many thousands of lives. They arise even yet in the filthy cities of Oriental countries, but are now far less destructive and more easily kept within bounds.

Our knowledge as to what the power of government can do to promote the health of a community has been increasing rapidly in recent years, but that knowledge is far from being thoroughly applied, because the people in general are not yet intelligent enough to demand it.

520. Knowledge of Sanitary Laws Essential to Good Citizenship. — In a free, democratic government, such as ours, proper attention to sanitary matters on the part of public officers depends upon an intelligent and active public sentiment. Since the people are the government, it is the duty of the people — all the people — to see to it that their servants, the officers appointed to protect them against the dangers of unsanitary conditions in any part

of the town or city, shall do their duty. No man be a really good citizen who is ignorant of the co tions which threaten the general health, or who negl to use his influence to keep the health officers wa ful and active. The subject of sanitation should th fore receive attention in our schools, and may prop be considered briefly in connection with the stud physiology.

521. **A Healthy Town or City** is one in which the poo inhabitants have pure air to breathe, pure water to dr wholesome, unadulterated food to eat, and opportun for cleanliness in person and dwelling. These condit can be supplied only by the strong arm of a central pc supported by an enlightened public opinion. And ha provided these prime necessities, the central powe government should require all citizens to make us them. A man should not be permitted to use the water from a filthy well, even on his own premises; to keep his own dwelling in so uncleanly a state a endanger the health of his own family and that of neighbors; if public washing conveniences are provi he should even, if necessary, be obliged to have the cl ing of his family cleansed and his own body bathed.

522. **Cleanliness the One Essential.** — The condition general physical well-being may after all be reduced one, viz. *cleanliness*, taken in its broadest, fullest se That would include clean air, clean water, unadultera food, cleanliness of person and clothing, and adequate ercise by which purity of blood is promoted and remo of the poisonous waste of the body is secured.

523. **Pure Air.** — A man can live for a considerable t without food or water, and he may within certain lin safely select what he will eat and drink. But he can

live for a single hour without air, and he is unable to select what air he will use, for he must breathe that which immediately surrounds him. Several things are needful that the air of a dwelling or other building may be fit to breathe.

(1) *Drainage of the Ground on which a House stands.* — More or less of the air in a building comes from the ground beneath and around it. A wet soil favors the multiplication of the bacteria always present in the ground, and among them are often germs of specific disease. Water is found at varying distances everywhere beneath the earth's surface, and, in order that a spot may be fit for building upon, what is called the *ground water* should be not less than fifteen feet below the surface (some authorities say thirty feet), and the level should not greatly vary from time to time. That a house may be healthful, the soil beneath it must be thoroughly drained by pipes laid deep enough in the ground; and public authorities should have power to see that this is done.

(2) *Ground Air should so far as possible be excluded from a House.* —The air in a house is usually warmer than that outside, and so there is a tendency to *suck up* the air in the porous ground below. Even if the soil is dry, there are often gases from decaying vegetation or other sources, which are more or less injurious to life, mixed with the earth. These should be excluded from the house by covering cellar walls and floor with an impervious coating. Care must also be taken that nothing is left to decay in the cellar or any other part of a building.

(3) *Sunshine is necessary to Health* and to the purity of the air in a house. No room is fit for human occupancy if it does not at some time receive the direct rays of the sun. Many dangerous germs are killed outright by direct

sunlight. Those persons who live habitually shut out f sunshine never have strong, buoyant health.

It is not yet common for public authorities to inter in respect to this matter. In our cities it is even permi to one citizen to cut off completely from his neighb family this prime necessity to well-being.

524. *The Air in Streets and Alleys* is often rendered of sive and dangerous by accumulations of filthy refuse f dwellings, stables, factories, etc. Neglect of prompt thorough cleansing of all such passages by the offi whose duty it is, should never be tolerated for a day, cleanliness of private premises should also be leg enforced.

525. Pure Food. — Governmental inspection of the v ous foods offered for sale is now recognized as an im tant duty. Diseased meat, adulterated milk, butter, l cheese, etc., are supposed to be excluded from the mark while adulterated sugars, baking powder, spices, etc., doubtless less common than formerly. But occasionall outbreak of typhoid fever or other fatal disease is tra to the carelessness or ignorance or cupidity of some de in dairy products, and hundreds of poor families are fo to be suffering in health from the adulterated bread flour or other necessary sold by an unscrupulous dea The inspection of foods should be made much more st and should be enforced in the smaller communities as v as in the large cities.

526. Pure Water. — Nothing is more essential to health of a community than an abundant supply of wh some water for drinking, and good citizens look well to source of their drinking water. Water from small strea rivers, or lakes is seldom, in thickly settled parts of world, pure enough for drinking until it has been trea

by some of the various methods now in use for freeing it from the unwholesome matters almost always present. It is true that running streams and lakes exposed to the action of sun and wind are purified to a considerable extent by natural influences, and where they do not receive an excessive amount of the waste of towns and factories, may usually be safely used. But very often the filth of a city or of several cities is poured continually into the lake or river which supplies the inhabitants with drinking water, the amount of poison being far more than nature is able to destroy. In such cases many and complicated devices are used for getting rid of the injurious substances. The water may be drawn off into large reservoirs and allowed to *settle*. Then, the coarser filth having been deposited, the water may be drawn into other reservoirs and treated with certain chemicals which will cause the *precipitation* of other substances as sediment. Some chemical substances destroy organic matter by oxidizing it, and sometimes the same result is obtained by forcing air through the contaminated water.

Water is also partly purified by *filtering* through various porous materials — large beds of sand, gravel, and broken stone, for instance. The filtering body itself soon becomes clogged with filth, and must be often renewed or cleansed.

None of these processes destroys all the dangerous germs to be found in impure water, and it is a wise precaution for every family to boil for half an hour all water for drinking which comes from a source liable to contamination. The water may then be placed in glass cans, tightly closed, and cooled in a refrigerator, or in a cellar. By this course much illness and death in large towns, where typhoid fever and other water-borne diseases are always

present, would be prevented. The same care shoul taken in the country, when the drinking water c from springs or shallow wells.

Probably the safest source of a water supply is *deep wells*, sunk far below any possible befoulment the surface. Many towns are now thus supplied. (nary wells and cisterns are seldom safe, unless great is used. The leakage from a barnyard or cesspool r rods away may find its way into a well through the l of earth, and poison the water. Rain water is mixed dust from the air and the roof, with bits of leaves other organic matter, and should be thoroughly fil and boiled for drinking.

Ice (unless manufactured from distilled water) con impurities, and should not be put into water usec drinking.

527. Public Bathing and Washing Conveniences are provided by the most progressive cities, and contri much to the health of the people. They should be or so nearly so that the poorest families may be ab enjoy the luxury of cleanliness.

528. Disposal of Garbage and Sewage. — Not only r the daily waste in towns and cities be gathered up removed from sight, but it must also be treated in s way which shall destroy its dangerous character. It r not be dumped upon vacant lots in the poorer quarte the town, and left to decay and poison the air. Ar is seldom safe to pour it into neighboring water way lakes. Various devices have been tried for the be disposal of the poisonous waste of human life, no or which is absolutely *best* for all localities. That whic most desirable for a particular community must be de mined in view of all circumstances and surroundi

No *cheap* and safe method has yet been discovered. All are expensive, but any one is cheaper than the sacrifice of life and health which is sure to result from unsanitary or slipshod ways of dealing with this serious problem. Some of the most satisfactory methods in use in the most progressive cities may be simply mentioned here.

Where a very large body of water is at hand, which is not the source of the town's water supply, the sewage may, for a time at least, be safely poured into it. This is the cheapest way. But such pollution of streams and lakes is now forbidden by law in many countries of Europe, as it should be in the United States. In some cities the sewage is collected in great vats, where the solid portion is separated from the liquid, and sold for use as a fertilizer. The liquid is by chemical treatment freed from its harmful ingredients, and poured into the water-courses. Some cities own large farms, to which the sewage is conveyed in close tanks, and spread upon the soil as a fertilizer. In other cases the soil is simply used as a filter. The sewage is spread upon it, and the liquid which filters through is received by drain tiles laid below the surface, and carried into a natural stream. The solid portion is decomposed by the action of air, sun, and bacteria, which render it harmless.

Garbage and the solid portion of sewage are frequently consumed in great furnaces, that which remains indestructible by fire being safely used for filling up low places about the city.

GLOSSARY

Ab-do'men (Lat.): the cavity of the body lying below the diaphragm and containing most of the digestive organs.

Ab-du'cens (Lat., leading away): the sixth pair of cranial nerves.

Ab-sorb'ents (Lat. *absorbere*, to suck in): the vessels which take up nutriment or waste matter.

Ab-sorp'tion: the process of taking up food from the alimentary canal or other substances from the tissues.

Ac-cel'er-a-tor (Lat. *accelerare*, to hasten): that which quickens, as an accelerator nerve.

Ac-com-mo-da'tion of the eye (Lat. *accommodare*, to fit): the adjustment of the shape of the crystalline lens for distinct vision at different distances.

Ac'id (Lat. *acidus*, sour): one of a class of chemical compounds usually sour to the taste, always soluble in water, capable of turning vegetable blue to red and of destroying the distinctive properties of alkalis or bases. Acids combine with bases to form salts, and then lose their own distinctive properties.

Ac-tin'ic energy (Gr. *aktis*, *aktinos*, ray): that form of force in light which produces chemical changes.

Ad'i-pose (Lat. *adeps*, fat): that form of tissue which forms or contains fat.

Af'fer-ent (Lat. *afferre*, from *ad*, to, and *ferre*, to bear): conducting inward or toward a center; opposed to *efferent*.

Al-bu'men (Lat. *albus*, white): white of egg.

Al-bu'min (Lat. *albus*, white): a substance composed of carbon, nitrogen, hydrogen, and oxygen, found in animals and plants, and an essential part of every living cell. It is found in its purest natural form in the white of an egg.

Al-bu'mi-noid: one of the foods containing nitrogen; a proteid.

Al'co-hol (Arabic *al-kohl*, fine powder of antimony, used in the East to paint the eyebrows with): the spirituous or intoxicating element of fermented or distilled liquors; or, in popular speech, any liquid containing it in a considerable quantity.

Al-i-men'ta-ry (Lat. *alimentum*, food): pertaining to food or concerned with nutrition.

Alimentary canal: the passage for the food, in which digestion takes place.

Al'ka-li (Arabic *al-kali*, *al-qaliy*, ashes of the plant saltwort): one of a group of caustic bases (such as soda and potash) which are soluble in water, have the power of neutralizing acids and forming salts with them, of uniting with fats to form soaps, and of changing the tint of many vegetable colorings — as of litmus reddened by acid — to blue.

Al-ve'o-lus (Lat., a small cavity): a small sac or vesicle; one of the air cells of the lungs.

A-mœ'ba (Gr. *amoibe*, change, exchange): one of the lowest forms of animal life, consisting of a single cell which is capable of many changes of form.

Am-pul'la (Lat., a narrow-necked vessel having two handles and swelling out below): one of the dilations of the semicircular canals of the ear.

A-nab'o-lism (Gr. *anabole*, something heaped up): the constructive processes of the body; opposed to *katabolism.*

A-nat'o-my (Gr. *anatome*, dissection, from *anatemnein*, to cut up): the science which treats of the structure of organic bodies.

An-te'ri-or: toward the head, or toward the front of the body.

An'ti-dote (Gr. *anti*, against, and *didonai*, to give): a substance that prevents a poison from injuring the tissues, when taken into the body.

An-ti-sep'tic (Gr. *anti*, against, and *septikos*, septic, making putrid): having the power to prevent putrefaction.

An-ti-tox'in (Gr. *anti*, against, and *toxikon*, poison): a substance which neutralizes the action of a toxin, or animal poison.

A'nus (Lat.): the opening at the lower end of the alimentary canal. through which the excrements are discharged.

A-or'ta (Gr. *aorte*, from *aeirein*, to raise, to lift): the great artery rising from the left ventricle of the heart.

Ap-pen-dic'u-lar skeleton: the pectoral girdle, the pelvic girdle, and the bones of the limbs.

Ap-pen'dix; plural **Ap-pen'di-ces** (Lat., from *appendere*, to hang): an appendage. The *vermiform appendix* is a small portion of the intestine, appended to the cæcum. The term *appendices* is given to the earlike projections from the auricles of the heart.

Aq′ue-duct of Syl′vi-us: a channel connecting the third and fourth ventricles of the brain. Named from the famous anatomist Dubois or Sylvius (the latinized form of the name).

A′que-ous hu′mor: the fluid filling the anterior chamber of the eyeball.

A-rach′noid (Gr. *arachnoeides*, like a cobweb): the middle one of the three membranes of the brain and spinal cord.

A-re′o-lar tissue (Lat. *areola*, diminutive of *area*, a broad space of level ground): a fibrous connective tissue with loosely woven fibers and many spaces.

Ar′gon (Gr. *argos*, lazy, inert): a gas forming about one per cent of the atmosphere; first recognized in 1895.

Ar′ter-y (Gr. or Lat. *arteria*, windpipe): one of the tubes conveying blood from the heart. They were formerly thought to contain air and to be branches of the windpipe.

Ar-tic-u-la′tion (Lat. *articulatus*, furnished with joints): any junction between bones in the skeleton.

A-ryt′e-noid cartilages (Gr. *arutainoeides*, shaped like a ladle, from *arutaina*, ladle, and *eidos*, form): two small cartilages of the larynx.

As-phyx′i-a (Gr. *a-*, without, and *sphuzein*, to throb, beat): apparent death from stoppage of respiration, as in suffocation from drowning or the breathing of certain gases.

As-sim-i-la′tion (Lat. *assimilatio*, from *assimilare*, to make like): the final process of anabolism, by which nutritive material is converted into the living substance of the body.

A-stig′ma-tism (Gr. *a-*, without, and *stigma*, *stigmatos*, prick of a pointed instrument, spot): a defect of the eye due to irregular curvature of the refractive media, by reason of which rays of light from a point are not brought to a single focal point. It results in indistinctness of vision.

At′las (Gr., one of the gods who bears up the pillars of heaven): the first vertebra of the neck, supporting the weight of the head.

At′om (Gr. *a-*, without, and *tomos*, cut): one of the ultimate indivisible particles of matter.

Au′di-to-ry os′si-cles: the three small bones of the middle ear.

Au′ri-cle (Lat. *auricula*, diminutive of *auris*, ear): a cavity at the base (upper portion) of the heart.

Au-to-in-tox-i-ca′tion (Gr. *auto*, self, and Eng. *intoxication*, poisoning): a poisoning of the system from the products of physiological processes or from the reabsorption of waste matter.

Ax′i-al skeleton: the bones of the head, neck, and trunk.

Ax′il-la-ry (Lat. *axilla*, the armpit): belonging to the armpit, as the axillary arteries.

Ax′is (Lat., axle): the second vertebra of the neck.

Ax′is cyl′in-der: the central core of a nerve fiber.

Ba-cil′li (plu. of mod. Lat. *bacillus*, diminutive of *baculum*, stick): microscopic, rod-shaped vegetable organisms; a variety of bacterium.

Bac-te′ri-a (plu. of *bacterium*, from Gr. *bakterion*, a staff): microscopic vegetable organisms, usually in the form of jointed rodlike threads. They are found in connection with putrefying matter. Some sorts cause disease.

Bi′ceps (Lat., having two heads, from *bis*, twice, and *caput*, head): the muscle on the inner side of the upper arm.

Bi-cus′pid valves (Lat. *bi*, two, and *cuspis*, a point): the valves guarding the opening from the left auricle of the heart into the left ventricle; the mitral valves.

Bicuspids: the two double-pointed teeth on each side of each jaw.

Bile (Lat. *bilis*): a greenish yellow fluid secreted by the liver. It passes into the small intestine, where it assists in the digestion of the food.

Bi-ol′o-gy (Gr. *bios*, life, and *logia*, discourse): the science of life.

Blind spot: an elevated surface on the retina where the optic nerve fibers enter the eye.

Brach′i-al (Lat. *brachium*, arm): pertaining to the arm, — as the brachial artery.

Bron′chi (Gr. *brogchos*, windpipe): the subdivisions of the trachea.

Cæ′cum (Lat. *cœcus*, blind): the first division of the large intestine.

Cal′ci-um (Lat. *calx*, *calcis*, lime): a chemical element found in lime, gypsum, and other substances.

Ca-nines′ (Lat. *canis*, dog): the sharp, pointed teeth next to the incisors.

Cap′il-la-ry (Lat. *capillus*, hair): one of the smallest blood vessels or other minute tubes.

Car-bo-hy′drates (*carbon* and *hydrate*): a class of foods which includes starch, the sugars, and cellulose. They are composed of carbon, oxygen, and hydrogen.

Car′bon (Lat. *carbo*, coal): a chemical element found in all organic compounds. Diamond and graphite are forms of carbon.

Carbon di-ox'ide: a gas composed of oxygen and carbon, always present in expired air; also called *carbonic acid gas.*

Car'bon-ate: a salt of carbonic acid, as limestone.

Car'di-ac (Gr. *kardia*, the heart): pertaining to the heart, as the cardiac nerves.

Ca-rot'id arteries (Gr. *karotides*, from *karos*, heavy sleep. The early Greeks believed these arteries in some way caused drowsiness): one of the two main arteries of the neck carrying blood from the aorta to the head.

Car'pus (Gr. *karpos*): the wrist.

Car'ti-lage (Lat. *cartilago*): a translucent elastic tissue; gristle.

Cartilages of San-to-ri'ni: little horn-shaped projections on top of the arytenoids in the larynx.

Cartilages of Weis'berg: small bits of cartilage in folds of the mucous membrane of the larynx.

Cell: one of the ultimate units of which all living bodies are composed.

Cel'lu-lose: the substance which constitutes the essential part of the solid framework of plants. It is a carbohydrate.

Cen'trum (Lat., center): the stout, bony body of a vertebra, to which is attached the neural arch.

Cer-e-bel'lum (Lat., diminutive of *cerebrum*, brain): the large lobe of the hind brain between the cerebrum and the medulla oblongata.

Cer'e-bro-spi'nal fluid: the watery substance which fills the cavities of the brain and the spinal canal, and bathes the outer surfaces of the brain and spinal cord.

Cerebro-spinal me-nin'ges (Gr. *menigx*, a membrane): the three membranes of the brain and spinal cord.

Cerebro-spinal men-in-gi'tis: inflammation of the membranes of the brain and spinal cord.

Cerebro-spinal system: the brain and spinal cord, with the nerves arising from them.

Cer'e-brum (Lat., brain): the anterior and principal part of the brain.

Cer'vi-cal (Lat. *cervix*, neck): of or belonging to the neck, as the cervical vertebræ.

Chem'i-cal a-nal'y-sis: the separation of a compound substance, by chemical processes, into its constituent elements.

Chemical element: a substance which cannot be decomposed by any known means into two or more kinds of matter.

Chlo′ride: a compound of the element chlorine with some other element, as chloride of sodium (common salt).

Cho′roid: the second of the coats of the eye. It contains a dark pigment.

Chyle (Gr. *chulos*, juice): a milky fluid containing partly digested food, and especially the fatty matter of the food in a state of emulsion.

Chyme (Gr. *chumos*, juice): the partly digested food as it passes from the stomach into the small intestine.

Cil′i-a (Lat. *cilium*, eyelid): small hairlike appendages lining certain organs, as the air passages.

Cil′ia-ry muscles: small muscles which help to adjust the eye for seeing at different distances.

Ciliary processes: radiating folds of the choroid of the eye at the outer edge of the iris.

Cir-cum-val′late pa-pil′læ (Lat. *circum*, around, and *vallum*, wall): a form of papillæ found at the back of the tongue and containing some of the taste end organs.

Clav′i-cle (Lat. *clavicula*, a little key): the collar bone.

Co-ag-u-la′tion (Lat. *coagulatio*): the change of a liquid to a thickened, curdlike state because of some chemical change.

Coc′cyx (Gr. *kokkux*, cuckoo): the end of the vertebral column beyond the sacrum.

Coch′le-a (Lat., a snail): a spiral bony tube of the internal ear.

Cœ′li-ac axis (Gr. *koilos*, hollow, and Lat. *axis*, axle, pole): a short, thick branch of the abdominal aorta given off just below the diaphragm.

Co′lon (Lat. and Gr.): the middle and longest division of the large intestine.

Color blindness: inability to distinguish colors.

Co′ma (Gr., lethargy): deep stupor from which it is difficult or impossible to rouse a person.

Con-duc-tiv′i-ty (Lat. *conducere*, to bring together): the power of passing on a stimulus from one point to others.

Con-ges′tion (Lat. *con*, together, and *gerere*, to bring): overfullness of the blood vessels of a part of the body.

Con-junc-ti′va (Lat. *conjunctivus*, connective): the mucous membrane covering the external surface of the eyeball and forming the lining of the lids.

Con-nect′ive tissues: tissues devoted to the support and connection of the muscles and nerves.

Con'scious-ness (Lat. *con*, together, and *scire*, to know) : knowledge of one's own mental operations.

Con-tract'ile substance (Lat. *contrahere*, to draw together) : the soft, half-fluid material of light and dark disks composing the muscle cells of voluntary muscles.

Con-trac-til'i-ty : the power possessed by living cells of changing form independently of pressure.

Co-or-di-na'tion (Lat. *co*, together, and *ordinare*, arrange) : the act of arranging in due order or relation.

Co'ri-um (Lat., a hide, leather) : the innermost layer of the skin ; the true skin.

Cor'ne-a (Lat. *corneus*, horny) : the transparent part of the coat of the eye which covers the iris and pupil.

Cor'o-na-ry arteries (Lat. *corona*, crown) : the arteries of the heart itself.

Coronary veins : the veins of the wall of the heart.

Cor'po-ra quad-ri-gem'i-na (Lat., fourfold bodies) : one of the five chief divisions of the brain ; called also the *optic lobes*.

Cor'pus-cle (Lat. *corpusculum*, diminutive of *corpus*, a body) : a minute particle or cell, as a blood corpuscle, a lymph corpuscle.

Cor'pus cal-lo'sum (Lat., callous body) : the great white band of nerve tissue connecting the hemispheres of the cerebrum.

Cor-re-late' (Lat. *con*, together, and *relatus*, referred) : to place in mutual or reciprocal relations ; to establish a relation of inter-dependence.

Cor'tex (Lat., bark) : an outer layer, as of the brain or the kidney. The cortex of the brain consists mostly of gray matter.

Cos'tal (Lat. *costa*, rib) : pertaining to the ribs or side of the body.

Cra'ni-al : belonging in any way to the cranium, as the cranial nerves or arteries.

Cra'ni-um (Lat., from Gr. *kranion*, the skull) : the human skull.

Cri'coid (Gr. *krikos*, ring, and *eidos*, form) : a circular cartilage of the larynx.

Cru'ra cer'e-bri (Lat., literally, the legs of the brain) : the bands of nervous matter connecting the cerebrum with the medulla.

Crys'tal-line lens : the principal lens of the eye, lying just back of the pupil.

Cu'ti-cle (Lat. *cuticula*, from *cutis*, the skin) : the epidermis or outermost layer of the skin.

De-cus-sa'tion of the pyramids (Lat. *decussatio*, crossing): the crossing of the bundles of white nerve fibers called the pyramids, in the medulla oblongata.

De-lir'i-um tre'mens (Lat. *delirium*, madness, and *tremens*, trembling): a disorder of the brain due to the excessive use of ardent spirits.

Den'tine (Lat. *dens, dentis*, tooth): the principal solid tissue of the teeth.

Der'mis (Gr. *derma*, the skin): the corium, or true skin.

Di'a-phragm (Gr. *diaphragma*, a partition wall): the membranous and muscular division between the thorax and the abdomen.

Dif-fer-en-ti-a'tion of tissues (Lat. *differentia*, difference): that modification in the structure of the tissues which adapts them to different functions.

Dif-fu'sion of gases: the homogeneous mixture which takes place in two gases placed in contact.

Di-ges'tion (Lat. *digestio*): conversion of food in the alimentary canal into products which can be absorbed into the blood.

Dor'sal (Lat. *dorsum*, the back): of or pertaining to the back, as dorsal muscles; opposed to *ventral*.

Duct: a tube or canal; especially one conveying secretion from a gland.

Du-o-de'num (Lat. *duodeni*, twelve each: because the length of the duodenum is about twelve fingers' breadth): the first division of the small intestine, next the stomach.

Du'ra ma'ter (Lat., hard mother. The membrane was once thought to give rise to every membrane of the body): the tough, fibrous membrane surrounding the brain and spinal cord and lining the cavities of the skull and spinal column.

Em'bry-o (Gr. *embruon*): the early form of an animal in development.

E-mul'sion (Lat. *emulgere, emulsum*, to milk out): a mixture of liquids which do not dissolve, the particles of one floating as small globules in the other; as fat (butter) in milk.

En-am'el: the hard outer part of the tooth.

End bulbs: one form of touch end organs.

End organs: special nerve cells or groups of nerve cells which receive and pass on the stimulus to which they are adapted.

End plate: the branching termination of a nerve fiber in a muscle *cell.*

En-do-car'di-um (Gr. *endon*, within, and *kardia*, the heart): the membrane lining the cavities of the heart.

En-do-skel'e-ton (Gr. *endon*, within, and Eng. *skeleton*): the inner bony framework possessed by vertebrate animals.

En-do-the'li-um (Gr. *endon*, within, and *thele*, nipple): the thin epithelium lining blood vessels, lymphatics, and serous cavities.

Ep-i-der'mis (Gr., *epi*, upon, and *derma*, skin): the outer layer of the skin, which is without blood vessels and nerves, and without sensation.

Ep-i-glot'tis (Gr., from *epi*, upon, and *glotta*, tongue): a lidlike sheet of cartilage which closes the glottis while food or drink passes into the pharynx.

Ep-i-the'li-um (Gr. *epi*, upon, and *thele*, nipple): the superficial layer of cells of the skin and mucous membrane, and of the blood vessels, lymphatics, etc.

E-soph'a-gus (Gr. *oisophagos*, the gullet): that part of the alimentary canal between the pharynx and the stomach.

E'ther (Gr. *aither*, from *aithein*, to burn, blaze): a thin, elastic medium supposed to pervade all space.

Eth'moid (Gr. *ethmoeides*, like a sieve): the bone through which the olfactory nerves pass out of the cranium.

Eu-sta'chi-an tube (named from *Eustachi*, an Italian physician): the small tube connecting the tympanum and the pharynx.

Ex-cre'tion (Lat. *excernere*, *excretum*, to sift out): the act of discharging from the body useless or worn-out material.

Ex-o-skel'e-ton (Gr. *exo*, without, and Eng. *skeleton*): the outer hard crust or covering of many of the invertebrate animals.

Ex-pi-ra'tion (Lat. *ex*, out, and *spirare*, to breathe): the act of breathing out; opposed to *inspiration*.

Fau'ces (Lat., throat): the narrow passage from the mouth to the pharynx.

Fe'mur (Lat., thigh): the thigh bone.

Fe-nes'tra (Lat.): a window. The *fenestra ovalis* and *fenestra rotunda* are the oval and round openings in the bone between the cavity of the tympanum and the labyrinth of the ear.

Fer'ment (Lat. *fermentum*, tumult, agitation): that which causes fermentation; as yeast.

Fer-men-ta'tion: the transformation of an organic substance into new chemical compounds by the action of a ferment.

Fi'brin (Lat. *fibra*, thread): a white fibrous substance formed in the clotting of the blood.

Fi-brin'o-gen: a substance in the blood which forms or helps to form fibrin, and thus causes clotting.

Fib'u-la (Lat., clasp, buckle): the outer and smaller of the two bones of the leg.

Fil'i-form pa-pil'læ: one form of the papillæ of the tongue, containing end organs for taste.

Fissure of Ro-lan'do: the furrow separating the frontal from the parietal lobe in the brain.

Floating ribs: the two lowest pairs of ribs, in man. They are not connected with the others in front.

Food: that which, taken into the alimentary canal, supplies material for the growth and repair of tissue, for the generation of force, or for the regulation of force.

Food elements: the five classes of food substances necessary to the health of the body, viz. proteids, carbohydrates, fats, water, salts.

Fo-ra'men mag'num (Lat. from *forare*, to bore, pierce; *magnus*, great): a large opening in the occipital bone of the skull, through which the spinal cord passes.

Fron'tal bone: the bone forming the front of the skull.

Func'tion (Lat. *functio*, from *fungi*, to perform): the appropriate action of any organ or part of an organism.

Fun'gi-form pa-pil'læ: one form of the papillæ of the tongue.

Gan'gli-on (Lat., a sort of swelling or excrescence, from Gr.): a little knot of nervous matter composed mainly of nerve cells.

Gas'tric (Gr. *gaster*, stomach): pertaining to the stomach, or situated near it; as the gastric juice, the gastric artery.

Gas-troc-ne'mi-us (Gr. *gastroknemia*, the calf of the leg): the chief muscle of the calf of the leg.

Gland (Lat. *glans, glandis*, acorn): an organ for secreting something to be used in or eliminated from the body.

Glo-mer'u-lus (Lat., diminutive of *glomus*, ball): one of the little bunches of looped capillary blood vessels in the cortex of the kidney, from which the uriniferous tubules arise.

Glos-so-phar-yn-ge'al nerves (Gr. *glossa*, tongue, and Eng. *pharyngeal*): the ninth pair of cranial nerves.

Glot'tis (Gr., from *glotta*, the tongue): the opening from the pharynx into the larynx.

Gly'co-gen (Gr. *glukus*, sweet, and *-gen*, producing): a substance belonging to the carbohydrates, found in animal tissues, and especially in the liver. It is believed to be deposited as a reserve material in the liver, and is converted into sugar as required. It is sometimes called "animal starch."

Goi'ter (Fr., from Lat. *guttur*, throat): a disease which causes an enlargement of the thyroid gland.

Hair fol'li-cle (Lat. *folliculus*, a small bag): a little pit or depression in the skin, from the bottom of which a hair grows.

Ha-ver'sian canals (named from *Havers*, a London anatomist): small channels in the bones through which the blood vessels ramify.

He'li-um (Gr. *helios*, the sun): a gaseous element identified in the sun's corona (hence the name) long ago, and now proved to exist in the earth's atmosphere, and in certain minerals of our planet.

Hem-o-glo'bin (Gr. *haima*, blood, and Lat. *globus*, a ball): the coloring matter of the red corpuscles of the blood.

He-pat'ic (Gr. *hepatikos*, of the liver): pertaining in any way to the liver, as the hepatic artery.

His-to-log'ic-al (Gr. *histos*, a web, and *logia*, speech): pertaining to histology, which is that branch of anatomy concerned with the minute, especially the microscopic, structure of the tissues.

Hu'me-rus (Lat., the shoulder): the bone of the upper arm.

Hy'a-line (Gr. *hualos*, glass): resembling glass; transparent, as hyaline cartilage.

Hy'dro-gen (Gr. *hudor*, water, and *-gen*, producing): one of the chemical elements; a very light gas. It unites with oxygen to form water.

Hy'gi-ene (Gr. *hugieia*, health): that department of knowledge which concerns the preservation of health.

Hy'oid bone (Gr. Υ, the letter upsilon, and *eidos*, form; from the shape of the bone): the bone at the root of the tongue.

Hy-po-gas'tric plexus (Gr. *hupogastrion*, the lower part of the abdomen): a nervous network lying on each side of the rectum.

Hy-po-glos'sal (Gr. *hupo*, under, and *glossa*, tongue): the twelfth pair of cranial nerves.

Il-e-o-cæ'cal valve (from *ileum* and *cæcum*): the valve at the junction of the small intestine with the large intestine. It prevents the contents of the latter from flowing into the former.

Il'e-um (Lat., groin): the last division of the small intestine.

Il'i-ac arteries (Lat. *ilium*, the flank): the arteries supplying the pelvis and its organs and the legs.

Im-mune' (Lat. *immunis*, free, exempt): exempt from a certain disease by nature, from inoculation, or from a previous attack.

In-ci'sors (Lat. *incidere*, to cut in): the eight front teeth.

In'cus (Lat., anvil): the middle one of the auditory ossicles, named from its anvil-like shape.

In-flam-ma'tion (Lat. *inflammatio*): a diseased condition of a part of the body, shown by excess of blood, swelling, and extra heat.

In-hi-bi'tion (Lat. *inhibere*, to restrain): the lowering or restraining of the action of a nervous mechanism by nervous impulses from a connected mechanism.

In-hib'i-to-ry: restraining.

In-nom'in-ate artery (Lat. *innominatus*, nameless): one of the great arteries rising from the arch of the aorta. It soon divides into the right subclavian and the right common carotid artery.

In-oc-u-la'tion (Lat. *inoculare*, to ingraft): the introduction of the germs of a disease through the skin, so as to give the disease.

In-spi-ra'tion (Lat. *in*, in, and *spirare*, to breathe): the act of breathing in.

In'su-la (Lat., an island): a portion of the cortex of the brain lying beneath the Sylvian fissure; also called the *island of Reil.*

In-ter-cos'tal (Lat. *inter*, between, and *costa*, rib): between the ribs.

In-tes'tin-al juice: the fluid secreted by the glands of the intestine. It plays some part in the digestive process.

In-tes'tine (Lat. *intestinum*): the long tube leading from the stomach to the anus; the bowels.

In-tra-cen'tral nerves (Lat. *intra*, within): those nerves which form lines of communication between the various nerve centers, as different parts of the brain and spinal cord.

In-ver'te-brates (Lat. *in-*, without, and *vertebratus*, vertebrate): animals having no internal vertebral column.

I'ris (Gr. and Lat., the rainbow): the colored portion of the eye, having in its center the pupil.

Ir-ri-ta-bil'i-ty (Lat. *irritare*, to excite): the power possessed by living cells of reacting under stimulus.

Je-ju'num (Lat., empty): the middle portion of the small intestine, between the duodenum and the ileum.

Ju′gu-lar vein (Lat. *jugulum*, collar bone, diminutive of *jugum*, yoke): one of the two large veins of the throat.

Ka-tab′o-lism (Gr. *kata*, down, and *ballein*, to throw): the destructive processes of the body; opposed to *anabolism*.

Kid′neys: glandular structures lying in the loins opposite the lumbar vertebræ. Their function is the purification of the blood by the excretion of urine.

Lab′y-rinth (Lat. *labyrinthus*, a structure having many intricate passages): the internal ear.

Lach′ry-mal gland (Lat. *lacrima*, tear): the gland which secretes the tears.

Lac′te-als (Lat. *lacteus*, milky): the lymphatic vessels which convey the chyle from the alimentary canal to the thoracic duct; so called from the color of the chyle.

La-cu′næ (Sing. *lacuna*, Lat., a pit): microscopic cavities in bone occupied by the bone cells.

La-mel′læ (Sing. *lamella*, Lat., a small plate of metal): layers of bone tissue arranged around the Haversian canals.

Lar′ynx (Gr. *larugx*): the enlarged upper end of the windpipe, containing the vocal cords.

Lig′a-ment (Lat. *ligare*, to bind): a band of connective tissue binding one part to another.

Liv′er: a large gland lying below the diaphragm on the right side. It secretes bile and performs other functions in metabolism.

Lum′bar (Lat. *lumbus*, loin): pertaining to or near the loins; as the lumbar arteries.

Lymph (Lat. *lympha*, clear water, a fountain): a colorless fluid filling the lymphatics and lymph spaces. It consists mostly of the fluid part of blood.

Lym-phat′ics: small transparent tubes arising in the tissues and conveying lymph.

Mag-ne′si-um: a light, silver-white metal.

Ma′lar bones (Lat. *mala*, the cheek bone, cheek): the bones of the cheek.

Mal′le-us (Lat., a hammer): the outer of the three auditory ossicles, named from its shape.

Mam′mal (Lat. *mamma*, the breast): an animal of the class mammalia, the highest class of vertebrates, containing all those which suckle their young.

Ma-nom'e-ter (Gr. *manos*, thin, and *metron*, a measure): an instrument for measuring the pressure of gases and liquids.

Master tissues: those tissues of the body which have to do with the liberation of energy, viz. the muscular and nervous tissues.

Mas-ti-ca'tion (Lat. *masticare*, to chew): the act of chewing the food.

Matter: that of which the sensible universe and all bodies are composed; anything which occupies space or is perceptible to the senses.

Max'il-la-ry bones (Lat. *maxilla*, jaw): the bones of the jaws.

Me-a'tus (Lat., a passage, from *meáre*, to go): a natural passage or canal. The *auditory meatus* is a tube of cartilage continuous with the pinna of the ear, and leading to the membrane of the tympanum.

Me-dul'la (Lat., marrow): a synonym for medulla oblongata. The term is also applied to the marrow of bones, and to the deep inner portions of the kidneys and other organs.

Medulla ob-lon-ga'ta (Lat.): the hindmost segment of the brain, continuous with the spinal cord.

Med'ul-la-ry cav-i-ty (Lat. *medulla*, marrow): the cavity in a bone which contains marrow.

Medullary sheath: the layer of white matter immediately surrounding the axis cylinder of a nerve.

Me-dul'la-ted: having the medullary sheath.

Mem'bra-nous coch'le-a: a membranous tube of the internal ear; also called the *cochlear canal.*

Membranous lab'y-rinth: a closed sac of membrane lying in the bony labyrinth of the ear.

Mes'en-ter-y (Gr. *mesenterion*, literally, the middle intestine): the membrane or one of the membranes which connect the intestines and their appendages with the hinder wall of the abdominal cavity.

Me-tab'o-lism (Gr. *metabole*, change): the processes by which living cells transform into their own proper substance material brought by the blood, and also break down and prepare for excretion matter which has fulfilled its function; anabolism and katabolism.

Met-a-car'pus (Gr. *meta*, beyond, and *karpos*, the wrist): the part of the skeleton between the wrist and the fingers, consisting of five bones.

Met-a-tar'sus (Gr. *meta*, beyond, between, and *tarsos*, the flat of the foot): that part of the skeleton between the ankle and the toes.

Mi'crobe (Gr. *mikros*, little, and *bios*, life): a microscopic organism; especially one of those forms which produce disease.

Mi'tral valves: the bicuspid valves of the heart, which are shaped like a miter.

Mo'lars (Lat. *molere*, to grind): the three back teeth on each side of each jaw.

Mol'e-cule (Lat. *molecula*, diminutive of *moles*, a mass): the smallest part into which a substance can be divided without destroying its chemical character.

Mo'tor areas: those portions of the cortex of the brain whose stimulation results in motion.

Motor nerves: nerves whose function it is to excite muscular contraction.

Mu'cous membrane (Lat. *mucus*, slime, and *membrana*, a skin, parchment): the lining membrane of all passages and cavities of the body which have an external communication.

Mu'cus (Lat., slime): a fluid secreted by the mucous membrane.

Mus'cu-lar sense: impressions conveyed by sensory nerve fibers running from the muscles to the spinal cord and thence to the brain, giving information of the general condition of the muscles, and helping to form judgments of weight, pressure, etc.

Nar-cot'ic (Gr. *narkotikos*, making numb): a substance which blunts the sensibilities, induces sleep, and, in large quantities, complete insensibility.

Nerv'ous impulse: the molecular disturbance which is conveyed by the nerve fibers from the point of stimulation to the nervous center in the brain or spinal cord, or from a nerve center to a muscle.

Neu'ral arch (Gr. *neuron*, nerve): the arch of a vertebra which incloses and protects the corresponding part of the spinal cord.

Neu-rax'on: the axis cylinder of a nerve fiber.

Neu-ri-lem'ma (Gr. *neuron*, nerve, and *lemma*, a husk): the primitive sheath, or inclosing membrane, of a nerve fiber.

Neu-rog'li-a (Gr. *neuron*, nerve, and *glia*, glue): a peculiar supporting tissue of the nervous system.

Neu'ron (Gr., nerve): the nerve unit, consisting of a nerve cell with its processes, one of which becomes the axis cylinder of a nerve fiber. Of such units the whole nervous system is composed.

Ni'tro-gen (Lat. *nitrum*, natron, and *-gen*, producing): a gaseous element forming four fifths of the atmosphere, and found in many important compounds.

Non-me-dul'la-ted: without the medullary sheath, as nonmedullated nerves.

Nu-cle-o'lus (Lat., diminutive of *nucleus*, a little nut): the nucleus of a nucleus.

Nu'cle-us (Lat., a little nut): a central modified mass of protoplasm found in nearly all cells.

Nu-tri'tion (Lat. *nutrire*, to nourish): a term which, in its broad sense, includes all the processes concerned in the growth, maintenance, and repair of the living body and all its parts.

Oc-cip'i-tal (Lat. *occiput*, the back of the head): pertaining to the hinder part of the head, as the occipital lobe of the brain.

Oc-u-lo-mo'tor (Lat. *oculus*, the eye): pertaining to the movements of the eye; applied especially to the third pair of cranial nerves.

O-don'toid process (Gr. *odontoeides*, tooth-shaped): the tooth or peg of the axis or second cervical vertebra.

Ol-fac'to-ry cells (Lat. *olfactus*, from *olere*, to have a smell, and *facere*, to make): the cells which are affected by odors; the end organs for smell, in the lining membrane of the nasal passages.

Olfactory nerves: the nerves of smell, distributed from the olfactory bulb over the membrane lining the nasal passages.

Olfactory tract: the band of nervous matter lying between the olfactory bulbs (from which the olfactory nerves spread out) and the roots of those nerves in the cerebrum.

O-men'tum (Lat.): a fold of the peritoneum.

O'pi-um (Gr. *opion*, poppy juice): the juice of the poppy, thickened into a sticky brown mass of bitter taste and peculiar odor. It is a stimulant narcotic, and powerfully affects the central nervous system.

Op'tic (Gr. *optikos*): pertaining to sight.

Optic chi-as'ma (Gr., two lines crossed): the crossing of the optic nerves.

Optic com'mis-sure (Lat. *con*, with, and *mittere*, *missus*, to place): the union of the optic nerve fibers from the two eyes, after passing through the openings in the eye sockets.

Optic thal'a-mus (Lat., chamber): masses of gray matter at the base of the cerebrum.

Or'bit (Lat. *orbis*, circle): eye socket.

Or'gan (Gr. *organon*, an instrument): one of the parts or members of a body which has some specific function; as the organ of vision.

Organ of Cor'ti (named from *Corti*, an Italian scientist): an epithelial structure within the membranous cochlea believed to contain the end organs for hearing.

Os in-nom-i-na'tum (Lat., nameless bone): the hip bone.

Os-mo'sis (Gr. *osmos*, impulsion, pushing): the diffusion of fluids through membranes.

Os'se-ous (Lat. *os*, bone): bony, made of bone; as osseous tissue.

Os-si-fi-ca'tion: the process of changing into bone.

O'to-liths (Gr. *ous, otos*, ear, and *lithos*, stone): minute hard particles in the passages of the inner ear.

Ox-i-da'tion: the chemical union of oxygen with other substances, as in combustion.

Ox-y-gen (Gr. *oxus*, sharp, acid, and *-gen*, producing, because erroneously supposed to be present in all acids): a gaseous chemical element found in the atmosphere and in many compounds.

Ox-y-hem-o-glo'bin: hemoglobin which has united with oxygen.

Pa-cin'i-an corpuscles (named from *Pacini*, an Italian physician): one of the forms of touch end organs.

Pal'ate (Lat. *palatum*): the roof of the mouth and floor of the nose. The *soft palate* is a fold of muscular membrane hanging between the back part of the mouth and the upper part of the pharynx.

Pan'cre-as (Gr. *pan*, all, and *kreas*, flesh): a gland in the abdomen near the stomach. It pours its secretion into the duodenum. In animals it is called *sweetbread.*

Pan-cre-at'ic juice: the secretion of the pancreas which acts upon the fats and proteids in the food.

Pa-pil'la (Lat., a nipple): a minute, rounded projection; as the papillæ of the tongue.

Pap'il-la-ry muscles: muscular bundles within the ventricles of the heart, attached to the heart walls and, by the tendinous cords, to the valves between the auricles and the ventricles.

Pa-ri'e-tal bones (Lat. *paries*, wall): bones of the cranium forming a part of the top and sides of the skull.

Pa-rot'id glands (Gr. *para*, near, and *ous, otos*, ear): the salivary glands near the ears.

Pa-tel'la (Lat., a small pan or dish): the knee pan.

Pec'to-ral girdle (Lat. *pectoralis*, pertaining to the breast): the clavicle and scapula upon each side, to which are attached the bones of the upper arms.

Pe-dun'cle: a band of nervous matter connecting different parts of the brain.

Pel'vic girdle (Lat. *pelvis*, a basin) : the two bones, one upon each side, called the os innominatum, to which are attached the bones of the upper legs.

Pel'vis (Lat., a basin) : the pelvic girdle and sacrum.

Pep'sin (Gr. *pepsis*, cooking, digestion) : a ferment found in the gastric juice.

Per-i-car'di-um (Gr. *pericardion*, around the heart) : the serous membrane which surrounds the heart.

Per-i-mys'i-um (Gr. *peri*, around, and *mus*, muscle) : the sheath of areolar tissue which surrounds a bundle of muscle fibers.

Per-i-neu'ri-um (Gr. *peri*, around, and *neuron*, nerve) : the membranous sheath surrounding a nerve.

Per-i-os'te-um (Gr. *peri*, around, and *osteon*, bone) : the membrane surrounding a bone.

Pe-riph'er-al (Lat. *peripheria*, from Gr. *peri*, around, and *pherein*, to bear, carry) : belonging to the outside or superficial portions of a body.

Per-i-stal'tic (Gr. *peri*, around, and *stellein*, to set, place) : pertaining to the waves of contraction, called *peristalsis*, running down the alimentary canal to force on the contents.

Per-i-to-ne'um (Gr. *peri*, around, and *teinein*, to stretch) : the serous membrane lining the abdominal cavity.

Per-spi-ra'tion (Lat. *per*, through, and *spirare*, to breathe) : liquid excretion from the skin, mainly from sweat glands.

Pha-lan'ges (Lat., plural of *phalanx*, a body of troops in ranks and files, from Gr. *phalagx*) : the bones of the fingers and toes.

Phar'ynx (Gr. *pharugx*, the throat) : that part of the alimentary canal between the cavity of the mouth and the esophagus.

Phos'phate: a chemical compound of phosphoric acid with a base.

Phos'pho-rus (Gr. *phos*, light, and *pherein*, to bring) : a chemical element; a white or yellowish waxy solid that gives off a faint glow.

Phre'nic (Gr. *phren*, the diaphragm) : belonging to the diaphragm; as the phrenic artery or nerve.

Phys-i-ol'o-gy (Gr. *phusis*, nature, and *logia*, discourse) : the science which treats of the phenomena of living organisms. It is divided into animal and vegetable physiology.

Pi'a ma'ter (Lat., kind, tender mother) : the delicate vascular membrane immediately covering the brain and spinal cord.

Pi′ne-al body (Lat. *pinea*, a pine cone): a glandlike body in the roof of the third ventricle of the brain.

Pin′na (Lat., a feather): the folded sheet of cartilage which forms the principal part of the external ear.

Pithed: deprived of the central nervous system by the passing of a wire or needle through the vertebral canal.

Plas′ma (Lat. and Gr., anything formed or molded): the colorless fluid of the blood.

Pleu′ra (Gr., a rib, the side): the serous membrane which covers the lungs and lines the cavity of the thorax.

Plex′us (Lat., a twining, braid, from *plectere*, to braid, twine): a network of vessels, nerves, or fibers.

Pons Va-ro′li-i (Lat., bridge of Varoli — an Italian anatomist): a band of nervous tissue on the front or ventral side of the medulla oblongata, connecting the two sides of the cerebellum.

Pop-lit′e-al (Lat. *poples*, the ham): pertaining to the ham or back of the knee, as the popliteal artery or ligament.

Por′tal circulation (Lat. *porta*, gate): the passage of venous blood from the capillaries of one organ to those of another before reaching the heart. In man, the circulation of the liver.

Portal vein: the large vein of the liver, bringing blood to its capillaries.

Pos-te′ri-or (Lat., coming after): away from the head, or sometimes, in human physiology, toward the back.

Po-tas′si-um (Eng. *potash*): a chemical element, found only in combination with acids.

Prim′i-tive sheath: the inclosing membrane of a nerve fiber.

Proc′ess (Lat. *processus*, a going forward): an outgrowth; a projection, as the spinous process of a vertebra.

Pro′te-ids (Gr. *protos*, first): the food elements which form tissue.

Pro′to-plasm (Gr. *protos*, first, and *plasma*, anything formed): an albuminoid substance consisting of carbon, oxygen, nitrogen, and hydrogen; capable under proper conditions of manifesting certain phenomena of life; "the physical basis of life."

Pty′a-lin (Gr. *ptualon*, spittle): the peculiar principle of saliva which acts as a ferment on starch, converting it into dextrose, a variety of sugar.

Pul′mo-na-ry (Lat. *pulmo*, a lung): pertaining to the lungs, as the pulmonary arteries, which carry blood from the heart to the lungs.

Pulmonary circulation: the circulation of the blood from the right ventricle of the heart through the pulmonary arteries, capillaries, and veins back to the left auricle.

Pu'pil (Lat. *pupilla*): the round opening in the center of the iris.

Pu-tre-fac'tion (Lat. *putrefactio*): the offensive decay of albuminous and other matter.

Py-lo'rus (Gr. *puloros*, gate keeper): the opening from the stomach into the intestine.

Ra'di-ant energy (Lat. *radiare*, to emit rays): the force resident in vibrations of the ether which fills all space.

Ra'di-us (Lat., a staff, rod, ray): one of the bones of the forearm.

Rec'tum (Lat. *rectus*, straight): the last division of the large intestine, and hence of the alimentary canal.

Re'flex action (Lat. *reflectere*, *reflexus*, to bend back): action in which afferent impulses reach a nerve center and efferent impulses are sent back without the higher brain centers having been stimulated. Such action is involuntary and often unconscious.

Re-frac'tion (Lat. *refrangere*, *refractus*, to break): the change in the direction of a ray of light in passing from one medium to another of a different density.

Re'nal (Lat. *renes*, kidneys): pertaining to or in the region of the kidneys, as the renal artery, the renal plexus.

Ren'nin (Anglo-Saxon *rinnan*, to run): that ferment in the gastric juice which causes milk to curdle; the element in rennet which assists in the making of cheese.

Re-pro-duc'tion (Lat. *reproducere*, to produce again): the process by which new organisms are produced from those already existing.

Res'o-na-ting cavities (Lat. *resonare*, to sound back, echo): the pharynx, mouth, and nasal cavities, slight changes in which modify the sound of the voice.

Res-pi-ra'tion (Lat. *respirare*, to breathe): the act of taking in and giving out air.

Re-spir'a-to-ry center: that cluster of nerve cells in the medulla oblongata which controls and coördinates the movements of the muscles concerned in breathing.

Ret'i-na (Lat. *rete*, a net): that membrane of the eye in which the fibers from the optic nerve terminate.

Rhyth'mic (Gr. *rhuthmos*, measured motion): characterized by a regular succession of movements, impulses, or sounds.

Rick'ets: a disease of early life characterized by defective nutrition of the bones, and often due to a lack of proper food.

Ri'gor mor'tis (Lat., rigidity of death): the condition in a dead animal body due to a coagulation of the protoplasm of the muscle cells.

Rods of Cor'ti: pillarlike cells forming part of the organ of Corti in the inner ear.

Sac'cule (Lat. *sacculus*, a little sac): part of the membranous labyrinth of the ear.

Sa'crum (Lat. *sacer*, sacred): the lower part of the spine, immediately above the coccyx.

Sa-li'va (Lat., spittle): the mixed secretions of the salivary glands and the mucous membrane of the mouth.

Sal'i-va-ry glands: the parotid, submaxillary, and sublingual glands which pour their secretions into the mouth.

Salt: a chemical compound formed by uniting an acid with a base. The salts which are food elements are chiefly chlorides, phosphates, and carbonates of sodium, potassium, calcium, and magnesium, with salts of iron and some organic acids.

Sar-co-lem'ma (Gr. *sarx*, flesh, and *lemma*, a husk): the membrane surrounding a striped muscular fiber.

Scap'u-la (Lat.): the shoulder blade.

Sci-at'ic nerve (Lat. *sciaticus*): the nerve of the hip and thigh.

Scle-rot'ic (Gr. *skleros*, hard): the outer coat of the eye.

Se-ba'ceous glands (Lat. *sebaceus*, from *sebum*, tallow): small glands under the skin which secrete an oily matter which softens and lubricates hair and skin.

Se-cre'tion (Lat. *secretio*, the act of secreting): the process by which the various glands separate material from the blood and elaborate it into new substances so as to form the various secretions, as bile, saliva, etc.

Se-cre'to-ry nerves: nerves that supply the organs of secretion.

Sem-i-cir'cu-lar canals: three half-circular canals of the internal ear.

Sem-i-lu'nar valves (Lat. *semi-*, half, and *lunaris*, from *luna*, the moon): valves of the heart, at the beginning of the aorta and of the pulmonary artery, which prevent the blood from flowing back into the ventricle.

Sen'so-ry areas: those portions of the brain whose stimulation results in sensation.

Sensory nerves: nerves which carry impulses resulting in sensation.

Se'rous: pertaining to serum; filled with, or secreting serum.

Se'rum (Lat., akin to Gr. *oros*, Skr. *sara*, curd): the watery portion of certain animal fluids, as blood, milk, etc.

Skull: the skeleton of the head.

So'di-um (Eng. *soda*): a chemical element found in union with various acids.

So'lar plexus: a network of nerves about the pit of the stomach, containing fibers from many different nerves.

Spec'trum (Lat., an appearance, image): the several rays of which light is composed separated by refraction and spread out in a band of colors and dark lines.

Sphe'noid (Gr. *sphenoeides*, wedge-shaped): an irregularly shaped bone in front of the occipital in the base of the skull.

Sphinc'ter (Gr. *sphigkter*, anything which binds tight): a muscle which surrounds and tends to close a natural opening.

Spi'nal (Lat. *spina*, the spine): pertaining to the backbone.

Spinal ac-ces'so-ry nerves: the eleventh pair of cranial nerves.

Spinal cord: the cord of nervous matter lying in the channel of the vertebral column, and continuous with the nervous matter of the brain.

Spiral ganglion: a mass of nerve cells in the inner ear.

Spleen: one of the ductless glands, lying in the abdomen near the stomach. Of its functions little is positively known.

Spleen pulp: a soft substance in the meshes of the tissue of the spleen.

Splen'ic: pertaining to the spleen; as the splenic vein.

Spu'tum (Lat., from *spuere*, to spit): that which is expectorated or discharged from the lungs.

Sta'pes (Lat., a stirrup): the innermost of the auditory ossicles, shaped like a stirrup.

Ster'il-ize (Lat. *sterilis*, barren): to render incapable of germination; to make sterile; to destroy the germs in food or water.

Ster'num (Gr. *sternon*, the breast): the bone in the middle of the front of the chest.

Stim'u-lus (Lat. for *stigmulus*, akin to *instigare*, to prick, to goad): any substance or agent capable of arousing the activity of a nerve or irritable muscle, or capable of producing an impression upon a sensory organ.

Stro'ma (Gr., a couch): the colorless framework of a red blood corpuscle or other cell.

Sub-cla′vi-an (Lat. *sub*, under, below): situated below the clavicle, as the subclavian arteries or veins.

Sub-lin′gual glands: the salivary glands under the tongue.

Sub-max′il-la-ry glands: the salivary glands under the jaw.

Su-pra-re′nal cap′sules (Lat. *supra*, above): two small bodies situated upon the kidneys. Their function is unknown.

Sus-pen′so-ry ligament (Lat. *suspendere, suspensum*, to suspend): a ligament attached to the crystalline lens and the ciliary processes of the eye. It assists in accommodation.

Su′ture (Lat. *sutura*, a seam): an immovable articulation, as one of those between the bones of the skull.

Syl′vi-an fissure: the furrow which divides the frontal from the temporal lobe of the brain; named from a famous anatomist Dubois, or Sylvius (the Latin form of the name).

Sym-pa-thet′ic nervous system: the double chain of ganglia lying on each side of the spinal column, with the nerves issuing therefrom, the plexuses which they form, and the small ganglia along their course.

Syn-o′vi-al (Gr. *sun*, together, and Lat. *ovum*, egg): of or pertaining to *synovia*, the fluid secreted by a synovial membrane and named from its resemblance to the white of egg.

Sys-tem′ic circulation: the general circulation of the blood throughout the body; opposed to the restricted pulmonary circulation.

Tar′sus (Gr. *tarsos*, the flat of the foot): the ankle.

Taste buds: end organs for taste found in certain papillæ of the tongue.

Tem′po-ral bones (Lat. *tempora*, the temples): complex bones situated in the side of the head, and containing the internal parts of the ear.

Temporal lobe: the part of the cerebrum lying on each side just beneath the temporal bone.

Ten′don (Lat. *tendere*, to stretch): a band or layer of dense fibrous tissue at the end of a muscle, attaching it to a bone, or between two muscular bellies; a sinew.

Tet′a-nus (Gr. *tetanos*, spasm): a gentle, continuous vibration, or prolonged contraction, as of a muscle or a nerve.

Tho-rac′ic duct (see *Thorax*): a large lymphatic vessel running upward through the thorax to empty into the jugular vein.

Tho′rax (Lat. and Gr., a breastplate, or the part of the body covered by a breastplate): that part of the body between the neck and the abdomen, and containing the heart and the lungs.

Thy'mus gland (Gr. *thumos*, the sweetbread): a ductless gland in the thorax behind the sternum. Its function is unknown.

Thy'roid cartilage (Gr. *thureoeides*, shield-shaped): a sheet of cartilage on the front of the larynx.

Thyroid gland: a ductless gland of unknown function in the region of the larynx.

Tib'i-a (Lat.): the inner and larger of the two bones of the lower leg.

Tis'sue: one of the materials of uniform structure forming the body, as muscular tissue.

Ton'sil (Lat. *tonsilla*): one of a pair of oval bodies situated in the recesses on each side of the fauces.

Touch corpuscles: one form of touch end organs.

Tox'in (Gr. *toxikon*, poison): a poisonous kind of the animal base or alkaloid which is formed in the putrefaction of albuminous matter.

Tra'che-a (Gr. *trachus*, rough): the windpipe.

Trans'verse ligament: a band of strong tissue dividing the large neural ring of the atlas into two parts, into one of which the odontoid process fits.

Tri'ceps (Lat., having three heads, from *tres*, three, and *caput*, head): the muscle at the back of the upper arm.

Tri-cus'pid valves (Lat. *tres*, three, and *cuspis*, point): the valves guarding the opening between the auricle and ventricle on the right side of the heart.

Tri-gem'i-nal nerves (Lat. *trigeminus*, born three together): the fifth pair of cranial nerves.

Troch'le-ar nerves (Lat. *trochlea*, a pulley): the fourth pair of cranial nerves.

Troph'ic nerves (Gr. *trophe*, nourishment): nerves which directly influence the nutrition of the tissues to which they go.

Tu-ber'cu-lin: a liquid prepared from cultures of the tubercle-bacillus, as a remedy for tuberculosis.

Tu-ber-cu-lo'sis (Lat. *tuberculum*, diminutive of *tuber*, tuber): a disease affecting most of the tissues, and characterized by the formation of tubercles and the tubercle-bacillus.

Tur'bi-nate bones (Lat. *turbinatus*, shaped like a top or cone): two small bones in the nostril chambers.

Tym'pa-num (Lat., a drum): the middle ear. The *membrane of the tympanum* is the eardrum.

Ul'na (Lat., the elbow): the inner of the two bones of the fore arm.

U're-a (Gr. *ouron*, urine, originally water): a crystalline solid, soluble in water. It is the final product of proteid decomposition in the body, and the chief solid constituent of the urine.

U-re'ter (Gr. *oureter*, from *ouron*, urine): the excretory duct of the kidney, conveying the renal excretion to the bladder.

U-ri-nif'er-ous tu'bules: small tubes which collect the urine secreted in the cortex of the kidneys.

U'tri-cle (Lat. *utriculus*): a little sac; especially the little sac forming part of the membranous labyrinth of the ear.

Vac-ci-na'tion (Lat. *vacca*, cow): inoculation with cowpox virus obtained directly or indirectly from the cow.

Va'gus (Lat., wandering): the tenth pair of cranial nerves.

Val'vu-læ con-ni-ven'tes (Lat. *valva*, the leaf of a double door; *connivere*, to wink at, connive): the semicircular folds in the lining membrane of the small intestine, increasing the absorbing surface.

Vas'cu-lar (Lat. *vasculum*, diminutive of *vas*, vessel): containing small vessels or tubes, as the vascular system for the circulation of the blood.

Vas-o-con-strict'or (Lat. *vas*, vessel, and Eng. *constrictor*, from Lat. *constringere*, to draw together): causing contraction of the blood vessels.

Vas-o-di-lat'or: causing dilation or relaxation of the blood vessels.

Vas-o-mo'tor: regulating the tension of the muscular walls of the blood vessels.

Vein (Lat. *vena*): one of the tubes carrying blood to the heart.

Ve'na ca'va (Lat., hollow vein): one of the great veins connected directly with the heart.

Ven-ti-la'tion (Lat. *ventilare*, to air, ventilate): the process of replacing foul or vitiated air in any confined space with pure air.

Ven'tral (Lat. *venter*, belly): toward the belly; opposed to *dorsal.*

Ven'tri-cle (Lat. *ventriculus*, diminutive of *venter*, belly): a cavity, as the ventricles of the heart or the brain.

Ver'te-bra (Lat., a bone of the spine): any segment of the backbone.

Ver'te-brates: animals having a backbone.

Ves'ti-bule (Lat. *vestibulum*, vestibule): the central part of the labyrinth of the ear.

Vil'lus (Lat., shaggy hair): one of the minute projections covering the valvulæ conniventes.

Vis′ce-ra (Lat., plu. of *viscus*, perhaps akin to Eng. *viscid*): the organs contained in the abdomen.

Vital knot: the nervous center in the medulla oblongata which presides over the coördination of the respiratory movements. If the medulla be divided below this center respiration ceases and death results.

Vit′re-ous humor (Lat. *vitreus*, of glass): the jellylike substance filling the posterior chamber of the eyeball.

Viv-i-sec′tion (Lat. *vivus*, living, and *sectio*, a cutting): dissection of a living body.

Vo′cal cords (Lat. *vox*, *vocis*, voice): bands of elastic tissue in the mucous membrane of the larynx which act upon the air like the reeds of a musical instrument to produce musical sounds.

Vo′mer (Lat., a plowshare): a small bone forming part of the partition between the nostrils.

Yellow spot: an area about one twenty-fourth of an inch in diameter in the retina of the eye, upon which the most definite images are formed.

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